Currency Hedging in Emerging Markets During Periods of Structural Change

by

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Declaration

The candidate does hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma in any university or equivalent institution. The work of the research program has been carried out since the official date of commencement of the program. To the best of my knowledge and belief, this thesis contains no material published or written by another person, except where due reference is made.

The paper "Yen Bloc or Koala Bloc? Currency Relationships After the East Asian Crisis" is taken from Chapter 5 and is forthcoming in *Japan and the World Economy*, and was presented at the European Financial Management Association conference in Helsinki, Finland in June 2003. The paper "Cointegration In The Presence of Structural Breaks" is taken from Chapter 6 and is forthcoming in *Global Finance Journal*. The paper "Cross-Hedging Effectiveness in Emerging Markets Experiencing Structural Change" is taken from Chapter 7 was presented at the European Financial Management Conference in Basel, Switzerland in July 2004.

Signed

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Abstract

Emerging market currencies rarely have exchange-traded futures which may be used to hedge spot positions. Cross-hedging is an alternative to direct hedging, and allows the spot position to be hedged using futures in a related asset. If the hedge is to be successful, there should be a significant relationship existing between spot and futures, and this can be determined using techniques such as correlation and cointegration testing. However, the presence of structural breaks may result in the relationship being misspecified, and any hedge that is formed based on this relationship is likely to underperform a more appropriately related hedge.

This thesis initially examines the relationships between a range of East Asian currencies, for which liquid, exchange-traded futures are unlikely to be available. The currencies are tested along with Australian dollar, Japanese yen and German mark futures, to determine if relationships exist. The period examined includes the 1997 East Asian crisis, when a number of the East Asian currencies experienced a change in regime, and it is anticipated that the currency series will contain structural breaks. A range of testing procedures is examined, with the performance of those accommodating structural breaks and those not accommodating structural breaks compared and contrasted. Breakpoints are identified using tests that do not rely on visual identification, but rather find the breakpoint from statistical analysis.

Currency pairs are then selected to form cross-hedges based on the results of cointegration and correlation testing, and the effectiveness of minimum variance and error-correction model hedge ratio derivation techniques are compared with the effectiveness of the traditional full hedge. Finally, the lower partial moment hedge ratio is examined. This technique, not previously applied to cross-hedges in the literature, is shown to be effective when used with cross-hedging, and is a promising avenue for future research.

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Dedication and Thanks

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1 Introduction

As the world continues to open its markets to international trade, the risks inherent in the free movement of capital through global financial systems become increasingly important to companies. Smaller companies are now just as likely to be involved in international trade as larger, multinational corporations, and as such are affected by exchange risk, political risk and other business risks caused by the globalisation of trade. It becomes important for companies to understand and manage this risk, and to do it while minimising costs and transaction fees. As a result, the use of hedging strategies to protect foreign currency denominated income streams has become an issue at the forefront of business planning and risk management. The ability to hedge using exchange-traded products is highly desirable as it allows businesses to minimise some types of risk while often minimising the costs associated with hedging.

Hedging is the process whereby the value of an asset is protected through the purchase of derivative products in the asset. The hedger is able to offset the risk inherent in the asset through the purchase of the derivative as the resulting portfolio of asset (spot) and derivative will carry less risk than the asset alone. For a simple example, suppose we are to receive USD $1000 in six months time. As the value of the money received (in AUD) will change as the exchange rate between USD and AUD changes, we have exchange rate or currency risk present in the transaction. In order to minimise this risk, it is possible to purchase a futures or forward contract that gives us the right to buy AUD for USD in six months time. If we are able to construct a scenario that allows us to buy the same number of AUD for USD $1000 in six months time as we would today, then we have created a perfect hedge and hence a guarantee that no money will be lost during the course of the transaction due to exchange rate movements[1]. This has effectively removed any currency risk from the transaction. In reality, the situation is more complex and a perfect hedge is rarely achievable. However it is possible to minimise the adverse consequences of international trade through the prudent and skilled use of various hedging techniques which allow the hedger to at least minimise their level of currency risk, if not remove it completely.

A variety of instruments exist that may be used to implement a hedge. Swaps, options, forwards and futures are commonly used in hedging, and merchant banks may create customised products that allow the hedger to precisely replicate their exposure. Other, more exotic instruments may also be created by the merchant banks to address the needs of the hedger. Alternatively, exchange-traded forwards, futures, options and futures options exist and many are widely traded. All of these products have been studied extensively, and there are arguments for and against the use of each type, although the consensus does tend to favour futures and forwards (Lien and Tse, 2002)[2]. This thesis will focus on the use of exchange-traded futures contracts in currency hedging. Exchange-traded derivative products enable hedges to be implemented quickly and cheaply. They are freely available and priced using market forces, which means that costs may be kept to a minimum. A custom-designed product, supplied by a merchant bank, is often less responsive to market forces and may be priced at a premium, although competition between banks can be fierce and a large company may be able to extract favourable concessions if their bank anticipates future business. Although the bank may be able to provide a product that is perfectly suited to the hedger's

[1] This is a very simplistic example and ignores other forms of risk. Particularly, in the case of a futures contract the mark-to-market risk must be considered.
[2] For a more complete discussion of these arguments, please refer to section 2.1.2, p. 31

requirements in all other respects, it is created entirely at the discretion of the bank and the terms of trade may mean that a purchaser is unable to exit their hedge early, or dispose of the product freely. An exchange-traded product may be priced more cheaply than a custom-built, over-the-counter product, and is easily traded in the market should a hedger wish to exit the strategy early, late, or on time. An exchange-traded product gives autonomy to the hedger, allowing them to trade at their discretion. It is also much more accessible for small businesses, who may not be able to justify a hedging strategy based on expensive, custom-built products. It also allows smaller denomination exposures to be hedged efficiently. Indeed, there is evidence that some banks may charge a "nuisance fee" to companies wishing to implement a smaller-valued hedge[3].

The difficulty of exchange-traded derivatives is that they come in a restricted range of assets, and only a few currencies have a liquid market in derivative securities. As a result, many currencies that are traded in the world today do not have exchange-traded derivatives available. This is particularly evident in East Asia, where previously managed exchange rates have floated in the last six years, and where less developed financial markets exist. However, these countries have become a manufacturing powerhouse, and are increasingly important to OECD countries for trade and investment. Not only are these countries producing large amounts of consumer goods for OECD consumption, but they have become important destinations for investment due to the spectacular growth of some of these economies. As studies such as Glen and Jorion (1993) and Harvey (1994) have pointed out, significant excess returns can be made by investing in emerging markets such as those in the Asian region while following a prudent hedging strategy to mitigate currency risk. Indeed, OECD-based

[3] These fees are discussed in Tormley (1992).

investors flocked to these markets during the 1990's as they exhibited spectacular equities market returns, and as their reputation as a reliable and cost-effective manufacturing base grew internationally. However, the nature of emerging markets is such that, while spectacular gains are possible, spectacular failures of the market are also a feature and a string of emerging market failures, from Mexico in 1994 to Argentina in 2002, lay testament to the dangers that may befall an unwary investor. Stories of financial ruin abound from this period. Investors who failed to implement effective hedging strategies were wiped out when the markets failed and currencies were forced to devalue. Few commentators forecast the Asian currency crisis and those that did were overlooked by investors (Radelet and Sachs, 1998a) as foreign investment funds flooded unchecked into the East Asian countries until the crisis hit. As most investors were caught completely off-guard by the severity of the crisis, many would have wished they had implemented a more effective hedging strategy. An investor with an unhedged exposure to the Asian markets in 1997 felt the full force of the subsequent financial crisis, and is doubtless wiser for the experience. A good hedging strategy that maximises gains while minimising losses will reward the investor in the longer term as it protects them from such crises. The lack of exchange-traded derivative products in Asian currencies is therefore a concern for the prospective hedger.

A solution to this problem is to use a cross-hedge. A cross-hedge is the process whereby the hedger uses a derivatives contract in a related but not identical asset to create the hedge. By implementing a cross-hedge in an appropriate currency, a hedge can be created that, while not as effective as an ordinary hedge (Eaker and Grant, 1987), can still yield good results and will protect a currency exposure more effectively than had the exposure been left unhedged. The hedge is best executed in a related currency, and hence the study of cointegration between East Asian currencies and those in which exchange-traded futures products are denominated is an important first step. By ascertaining which currencies are related to the currency we wish to hedge, it may be possible to create a cross-hedge that will be cheaper to buy, more accessible and more flexible in its disposal than those custom-made by merchant banks. This effectively minimises the risk inherent in foreign currency transactions while taking advantage of a typically liquid, mature market for derivative securities.

The choice of a related currency may then be made using cointegration analysis. Engle and Granger (1987) show that a linear combination of two time series will have an error term that is *I(0)* if those time series are cointegrated. This means that they have a relationship in which one moves in some combination with the other, and hence these are closely related assets in mathematical definition. If cointegration analysis indicates that two currencies are cointegrated, then this relationship can be exploited in a cross-hedge. Thus the currencies of a region, such as East Asia, may be tested for cointegration against a variety of OECD currencies with liquid exchange-traded derivatives markets to find an appropriate cross-hedging instrument.

It is interesting to note that most studies of cross-hedging focus on northern hemisphere currencies such as the US dollar, the German mark, the British pound and the Japanese yen. There is little consideration for another currency that is traded in significant volume[4], and which has a wide range of derivative products available – the Australian dollar. Further, what little work has been done on the East Asian region fails completely

[4] Bank for International Settlements (2005) indicates that the Australian dollar is the 6th most highly traded currency in the world, ahead of the Canadian dollar and just behind the Swiss franc. (Table B.3, "Currency distribution of reported foreign exchange market turnover", p. 9). In Asia, only the Japanese yen is more highly traded.

to take the Australian dollar into consideration. Intuitively it would seem that this is a gross omission, considering the nature of Australia's diplomatic and trade relationships in the region. Australia exports 53% of its merchandise trade to Asia, and as the only major "western" economy in the region it has a pivotal political role in both diplomacy and aid work. This thesis rectifies this omission by showing that the Australian dollar is a major influence on the currencies of East Asia, particularly so since the floating of the currencies in 1997-98. This is the first comprehensive characterisation of the relationships between the East Asian and Australian currencies, and the first that examines the changing nature of their relationships over the currency crisis period.

Once a suitable hedging currency has been identified, a cross-hedge can be put in place. The exact nature of the hedge is another essential part of the hedging strategy. A variety of hedging techniques exist, from the Ederington (1979) minimum variance hedge ratio, to GARCH model hedge ratios, error-correction model hedge ratios and methods incorporating lower partial moments. This thesis will examine a range of these techniques for the derivation of hedge ratios, and contrast them with the performance of the full hedge using a variety of performance measures. The ability to use some ratio, rather than a full 1:1 hedge, significantly decreases the costs associated with hedging as it requires the purchase of fewer derivative securities[5], and much work has been dedicated to the quest for the ideal hedge ratio derivation technique. In this thesis, a range of widely-used hedge ratio calculation methods will be used to determine the most effective technique to use when cross-hedging East Asian currencies. This would give an indication of the preferable technique to use with future cross-hedges in other

[5] Chaput and Ederington (2005) observe that "transaction costs should be an increasing function of ... the total number of [derivatives] or assets making up the combination" (Chaput and Ederington, 2005, p. 249).

currencies which are also unable to be directly hedged. To date no studies have attempted a comprehensive overview of hedging techniques that may be used to cross-hedge East Asian currencies, and this is particularly relevant considering the emerging nature of their economies and the importance of hedging during periods of economic instability. This review seeks to identify optimal techniques for hedging Asian emerging market currencies during periods of structural change, and make recommendations that may be applied during such periods in the future. As trade between Australian and Asia increases, it is essential that Australian companies are knowledgeable of sound hedging strategies that may be applied simply and with confidence to protect their overseas exposures and ensure the viability of their business activities.

Of critical importance to this thesis is the period of structural adjustment undergone by the East Asian currencies during the currency crisis in 1997. At this time, economic meltdown in the East Asian region resulted in significant changes to both economies and currencies. As a result of both changes in monetary policy and through the significant economic realignment that took place during and after the crisis, the nature of the currencies changed significantly. With the notable exception of Malaysia, which moved to a fixed peg regime in late 1998, the regional currencies are now characterised as floating regimes, while previously managed peg regimes had been the most common currency regime in the Asian region. This has resulted in significant structural change in the nature of the currency time series, and as such any analysis that incorporates this time period must take this structural change into account.

Bekaert and Harvey (1997) observe that equities in emerging markets have significantly different characteristics to those in developed capital markets, and it can be anticipated that emerging market currencies may also behave differently to those of developed economies. Certainly in any study of cointegration, it is vital to ascertain the nature of the currencies as defined by characteristics such as skewness, kurtosis and standard deviation. By breaking the currencies into pre- and post-crisis sub-periods, it is possible to see evidence of significant structural changes. Further analysis using unit root tests and cointegration tests also highlight the changes that took place, and form a basis for further investigation.

However, when analysing the unit root or cointegration properties of time series, most tests fail to take structural changes into account. In this instance, results will be generated that may be misleading, so it is important to use tests that allow for the possibility of structural change. The Zivot and Andrews (1992) test for a unit root and the Gregory and Hansen (1996) test for cointegration allow for the impact of structural change, and are contrasted in this thesis with traditional testing methods in order to ascertain their ability to correctly characterise data during periods of readjustment. This is the first time that the Gregory and Hansen test has been used to analyse cointegrating relationships between currency pairs, and is of particular interest due to the structural change that takes place during the study period.

The importance of hedge performance over such periods cannot be overstated. It is precisely times such as this that hedges are particularly desirable in order to minimise the impact of adverse currency movements. A superior hedging strategy will deliver significant benefits to the hedger and allow them to minimise losses. This thesis aims to highlight the role of Australia in the East Asian region, showing that it is a currency, and hence an economy, of importance to regional trade and that this is reflected in the levels of cointegration between the East Asian and Australian currencies. Further, the application of effective hedging strategies can greatly benefit Australian companies investing in East Asia, allowing them to mitigate risk while maintaining their anticipated returns. This thesis will demonstrate optimal hedging strategies and provide recommendations that may be used by companies to minimise investment risk. The lack of previous research in this area is an oversight on the part of the primarily northern hemisphere-based researchers that have carried out prior studies on East Asian currency markets. This thesis aims to rectify this oversight, and provide valuable information that may be practically applied by the ever-increasing numbers of Australian investors in East Asia.

This thesis proceeds as follows: Chapter 2 gives an overview of the literature in the field of currency, derivatives and hedging, with particular focus on East Asian currencies, hedge ration derivation methods and cross-hedging. Chapter 3 provides a brief background on the countries and currencies of East Asia, and the cause and effects of the 1997 East Asian crisis. Chapter 4 discusses the data used throughout this thesis. Chapter 5 examines the relationships between East Asian and range of developed economy currencies, revisiting particularly studies of a "yen bloc" in Asia and seeing if behaviours observed in the early 1990s still hold true in the wake of the 1997 crisis. Chapter 6 further analyses the currencies to find pairs of related currencies that could be used in cross-hedges. Chapter 7 implements cross-hedges using full hedges and a selection of minimum variance ratio hedge techniques to see if hedging during the crisis would have better managed exchange rate risk for those investors with East Asian currency exposures. Chapter 8 implements lower partial moment hedges, previously unexplored in cross-hedging, to see if this technique improves the performance of cross-hedges during the crisis. Chapter 9 then concludes and discusses the potential for further research.

2 Literature Review

Hedging is the process whereby those who deal in a commodity can transfer the risk of price changes in that commodity to other market participants who willingly bear the risk in anticipation of rewards. Traditionally, the decision to hedge was motivated by the preference of the commodity dealer for greater certainty of future earnings, and was based in the commodities markets of farm and mining products. In these early days, the futures market was regarded as a convenient place for commodities producers to offload the burden of market risk on to those willing to speculate on future returns. As the financial markets became more sophisticated a wider range of hedging products became available that allowed the risk inherent in the purchase or sale of most financial products, including currency, shares and indices, to be diversified away through the use of derivative products. With the importance of global investment and the use of portfolio management techniques, financial managers will consider hedging strategies as part of their overall management plans. This concern is not limited to the financial services industry - Marshall (2000) surveyed 200 multinational corporations in the Asia-Pacific region[6] and found that 87% of managers were concerned about managing foreign exchange risk. This makes the discipline of hedging highly relevant in the modern marketplace.

This chapter begins with a discussion of the motivation to hedge, and the three main theories behind this: traditional hedging theory, Working's (1953) theory of speculation on the basis, and portfolio theory. With portfolio theory came new developments in the understanding of hedging, particularly the concept of hedge ratios. Traditional hedging theory proposes that a hedge should be based on a fundamental 1:1 ratio, where a

[6] Consisting of Australia, Japan, Hong Kong, Singapore and South Korea

derivative product is purchased to match each equivalent unit of asset value. Research, including that of Ederington (1979), explored the concept of hedge ratios further and began the quest for the superior hedge ratio which reduced risk while allowing a smaller quantity of derivatives to be used to create the hedge. While the range of products available to prospective hedgers has increased, there has been little improvement in the use of ratios as cost minimisation and risk reduction strategies in the marketplace. Classic hedging case studies include that of Metallgesellschaft, which used basic 1:1 ratios while implementing more complex strategies based on product purchasing[7]. A cynic might suggest that this is because the purchase of more derivatives products results in greater profits for the sellers of the products, namely the merchant banks, and perhaps it is not in the best interest of the banks to limit the quantity of products sold. Regardless, there have been many advances in hedge ratio calculation since Ederington's work, and this chapter continues with a discussion of this research.

Research into cross-hedging techniques is incomplete without a detailed investigation of the relationships between the assets that the hedger wishes to use when constructing their hedge. For the purposes of this thesis, this investigation will focus on currency and currency derivatives. A survey of the literature relating to the analysis of currencies and of cointegration techniques concludes this chapter, with particular reference to unit root and cointegration methods that accommodate structural breaks in time-series data. As the study period includes the changes that took place in East Asian currencies during 1997, it is important that any analysis of these currencies accommodates structural breaks.

[7] Lien and Tse (2002) discuss Metallgesellschaft's use of a complex rollover strategy, noting that a traditional full hedge was used.

2.1 Hedging Theory

There are three primary streams of thought on the motivation to hedge. The first is traditional hedging theory, which describes the hedge as a precautionary measure designed to protect the value of a portfolio and eliminate risk. Originally, primary producers would offload their market risk by selling their produce forward, locking in a certainty of earnings and allowing speculators to purchase their price risk from them, and so hedging could be regarded as having a "protective" feature. This "protective" feature of hedging is defined by Graf (1953) as being based on an assumption that the prices of an asset and its derivative are so similar that a change in the price of the asset will be appropriately offset by a change in the price of the derivatives. However, it did not take long for the concept of hedging as "protection" to fall out of favour. One element was the inconsistency between actual observed behaviour with this traditional theory – participants in the market were not necessarily using full hedges, and were participating in speculative behaviour. Graf shows that hedging does not provide a comprehensive "protection" solution for a hedger, with the theoretical benefits of hedging not always being realised *ex-ante* and Graf concludes that "(h)edging by no means removes all of the risk associated with cash price changes ... and many hedges result in little or no protection"[8]. Indeed, it became evident that many participants in the futures market were speculators, and that hedging comprised of a speculative component described as "speculation on the basis" by Working (1953). Working proposes that the role of a hedge is not merely to provide a form of insurance for some future cashflow, but that the hedge itself should produce some return. Working describes a hedge as an arbitrage between cash and futures prices – this difference being

[8] Graf (1953), p. 413

known as the basis[9]. In the Working view of hedging, the profit derived from the hedge is more important than the "protection" aspect of the hedge, and hence risk reduction is not necessarily the primary purpose of a hedge. Rather, the hedgers choose to expose themselves to basis risk – and so the concept of the hedge as "speculation on the basis" arises. The perfect hedge will have no change in the basis, and as such no arbitrage can take place. But in the real world, there is no perfect hedge, and Working argues that it is this differential that motivates the hedger. Indeed, it is the expectation of a favourable change in the basis that determines whether to put the hedge in place, and Working contends that the primary purpose of a hedge is to create a profit maximising transaction.

However, a third theory of hedging emerged with portfolio theory. Johnson (1960) and Stein (1961) promote this perspective and base the motivation to hedge on the level of risk aversion of the investor, risk being measured as portfolio variance. They introduce models of optimal hedging strategy based on indifference curves and the efficient portfolio frontier, and demonstrate that both the traditional and Working views of hedging can be incorporated under this model as special cases. Johnson discusses in detail the concept of both protection and speculation as special cases of the portfolio theory of hedging. Johnson uses indifference curves to show that the Working viewpoint is a single market model of the portfolio theory of hedging, while also showing that under certain circumstances it will be optimal for the Working motivated investor to move to a portfolio approach. This explained some behaviour observed in the market that contradicted the original two hedging theories.

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[9] Basis risk can be described as the risk inherent in the difference between spot and futures prices.

Further support for the portfolio model of hedging came with the work of Ederington (1979). Ederington shows that the full hedge, where one unit of asset is matched with one unit of derivative to form a hedge, is not necessarily optimal and that an alternative ratio can be derived with the purpose of minimising the variance of a spot/futures portfolio. Ederington's support for the portfolio theory of hedging is based on the underlying premise that

$$Var(P) < Var(U) \tag{1}$$

that investors desire the variance of the hedged portfolio, *Var(P)*, to be less than that of the unhedged portfolio, *Var(U)*. Using the theory of adaptive expectations, it is possible to show that if the futures price incorporates market expectations, then movements in futures prices should not normally match changes in spot prices but rather be some proportion of spot prices. This means that the potential for a perfect hedge is small, and that traditional "protection" motivations may be unrealistic. Ederington proposes that a ratio can be derived that specifies how much of a fixed spot holding should be hedged, based on the risk profile of the portfolio. This ratio can be determined by minimising the risk of the portfolio:

$$R(P) = (S_{t=T} - S_{t=0}) - \beta(F_{t=T} - F_{t=0}) \tag{2}$$

where *R(P)* is the return on the (hedged) portfolio,

S_t is the spot (asset) price at time t,

F_t is the futures price at time t,

and β is the ratio of futures to spot in the portfolio.

Hence the return on the portfolio at time T is a function of the return on the spot minus the appropriate ratio of the return on the futures held in the portfolio. The variance of the portfolio σ^2_P is then given by:

$$\sigma_P^2 = \sigma_S^2 + \beta^2\sigma_F^2 - 2\beta\rho_{SF}\sigma_S\sigma_F \tag{3}$$

where σ^2_S, σ^2_F are the variances of the spot and futures respectively,

and ρ_{SF} is the coefficient of correlation between the spot and futures.

To minimise the variance with respect to the hedge ratio β gives:

$$\frac{\partial\sigma_P^2}{\partial\beta} = 2\beta\sigma_F^2 - 2\rho_{SF}\sigma_S\sigma_F \tag{4}$$

Setting this first order condition equal to zero to obtain minimum variance gives the solution for β, the minimum variance hedge ratio:

$$\beta = \rho_{SF}\frac{\sigma_S\sigma_F}{\sigma^2{}_F} \equiv \frac{\sigma_{SF}}{\sigma_F^2} \tag{5}$$

and hence the ratio is derived from the covariance/variance properties of the asset being hedged. This ratio β is generally known as the Ederington minimum variance ratio, or EMV. Ederington proposes that the success of this hedge should be measured by the reduction in variance of the hedge, such that

$$\begin{aligned} e &= 1 - \frac{Var(P)}{Var(U)} \\ &= \frac{\sigma_{SF}^2}{\sigma_S^2\sigma_F^2} \\ &= \rho_{SF}^2 \end{aligned} \tag{6}$$

When implementing a hedge, this is the sample coefficient of determination R^2, and has become known generally as the R^2 measure. This measure is discussed in more detail later in this chapter.

Ederington shows that for a range of portfolios, created from historical data on a variety of futures products, the optimal hedge ratio β is usually less than 1, and thus in a pure risk-minimisation hedge the optimal solution is unlikely to be the traditional full (1:1) hedge. Ederington supports the contentions of Johnson and Stein that both the traditional and Working views of hedging are special cases of portfolio theory, and illustrates the "protection" viewpoint using the minimum-variance scenario. Castellino (1992) takes this further, showing that both the Working viewpoint and the traditional "protection" viewpoint are supported by the minimum hedge ratio by demonstrating that the hedge ratio can be broken down into two components, a basis component B consisting of a combination of spot and futures, and what Castellino defines as a speculative component consisting of the futures contracts. From equation (2), Castellino separates out the components of the variance of the hedged portfolio σ^2_P such that:

$$R(P) = [B_{t=T} - B_{t=0}] + [1-\beta][F_{t=T} - F_{t=0}] \tag{7}$$

where $B_t = S_t - F_t$ describes the basis at time t,

and $R(P)$ is the return on the portfolio P. The expected return E of the hedged portfolio P is therefore

$$E(P) = [E(B_{t=T}) - B_{t=0}] + (1-\beta)[E(F_{t=T}) - F_{t=0}] \tag{8}$$

From this it can be seen that the basis component of the expected return $E(P)$ is not affected by the hedge ratio β, while the speculative, or futures price biasedness, component of the return is a function of the hedge ratio β. If there is no futures price bias, then the expected return on the hedge is simply the change in the basis, and the profit is unaffected by the hedge, satisfying Working's theory. The decision to hedge is based on expectations of future profits derived from the basis, and any decision to use a ratio is secondary to this profit motive. However, if prices are assumed to be biased, then the portfolio theory model allows the hedger to make a trade-off between risk and return dependent on the hedger's utility function.

Other research has examined these concepts further. Stulz (1984) derives optimal hedging policies for risk-averse firm managers, who are pursuing a value-maximising corporate policy and who are seeking to hedge currency risk. If the management of the firm are goal-aligned with shareholders in their pursuit of firm value maximisation, Stulz shows that the firm will pursue an active hedging policy, and that the optimal hedge in these circumstances is not a full hedge. Dale (1981), Naidu and Shin (1981), Hill and Schneeweis (1981) and Glen and Jorion (1993) demonstrate the use of the Ederington minimum variance hedge empirically by examining OECD currencies and finding that the optimal hedge ratio is often less than 1, and that the Ederington minimum variance ratio is generally more effective in managing variance risk than a full hedge. These studies find that the implementation of a minimum variance hedge significantly decreases the risk of a portfolio, and so satisfies the portfolio theory objective of the hedge where risk minimisation is at least as important as the portfolio return. Indeed, the theory of hedging has now progressed to a point where researchers are confident to state, as did Ghosh (1993a), that "(t)he objective of hedging is to minimise the risk of the portfolio for a given level of return"[10].

[10] Ghosh (1993a), p. 743

2.1.1 Hedge Ratio Calculation

Since Ederington's (1979) work on hedge ratio calculation, there have been various methods explored that can be applied to calculate optimal hedge ratios under different characterisations of the data, depending on the understanding of the underlying time series behaviour of the asset being hedged and the utility function of the hedger. There are two main strands of literature regarding hedge ratio optimisation: one in which the hedge ratio seeks to minimise variance and hence provide a constant return, and another in which the hedge ratio seeks to address both the risk and return profiles of the hedger and provide a ratio that allows some non-zero return in exchange for some risk. Addressing the former, Ederington popularised the notion that the optimal hedge ratio was not necessarily the traditional 1:1 relationship previously assumed. Since then, there have been significant developments in the estimation of minimum variance hedge ratios, many based on subsequent research into the underlying properties of financial time series. The development of ARCH, GARCH and error-correction models have seen a variety of hedge ratio calculation methods popularised that optimise the ratio based on the characteristics of the series being hedged. A second strand of research has attempted to maximise investor return according to their risk profile, and will be discussed subsequently.

Ederington's minimum variance hedge ratio derivation is based on ordinary least squares (OLS) regression. The simple regression level analysis of this is shown in the following equation:

$$S_t = \alpha + \beta F_t + \varepsilon_t \tag{9}$$

where S_t is the return on the spot at time t,

F_t is the return on the futures at time t,

α, β are intercept and trend terms respectively,

and ε_t is a random noise term.

Hence the return on the spot at time t is a function of the return on the futures contract at time t, while the solution for the trend term β is the minimum variance hedge ratio. This derivation of β has become known as the Ederington Minimum Variance (EMV) ratio, although it is sometimes referred to in the literature as simply the minimum variance ratio[11]. Further, Ederington used the concept of R^2 to determine the "goodness of fit" of the hedge ratio. R can be defined as the coefficient of correlation between the spot and futures contract, with R^2 representing the coefficient of determination. R^2 is commonly used to assess hedge ratio effectiveness for in-sample performance. The R^2 measure can be defined as the fraction of the variance of the dependent variable that is explained by the independent variables, and will equal 1 if the model fit is exact, or 0 if there is no model fit. Castellino (1992) shows that the expected profit or loss generated by the hedge will be unaffected by the hedge ratio if futures prices are unbiased predictors of future spot prices. The implementation of an Ederington minimum variance ratio hedge in these circumstances will successfully reduce variance risk, while there will be no profit on the basis. In the event that bias exists, then profits can be made by choosing to hedge in expectation of returns from the price biased component. Further, Castellino highlights the fact that as the basis risk is a function of time to maturity, then so too is the EMV ratio.

[11] As this work will examine several ratios that minimise variance under defined assumptions, this ordinary least squares-derived ratio will be referred to explicitly as the Ederington minimum variance, or EMV, ratio.

Castellino shows that the minimum variance hedge ratio at time t can be described as:

$$\beta(t) = 1 + \frac{Cov[B(t,T), F(t,T)]}{Var[F(t,T)]} \tag{10}$$

where $F(t,T)$ is the futures price at time t for a contract with expiry date T,

$B(t,T)$ is the basis at t i.e. $S(t) - F(t,T)$ where $S(t)$ is the spot price at time t,

and

$$Var[F(t,T)] = t\sigma_F^2, \tag{11}$$

$$Var[B(t,T)] = \left[\frac{T-t}{T}\right] t\left[\sigma_S^2 + \sigma_F^2 + 2\rho_{SF}\sigma_S\sigma_F\right] \tag{12}$$

and

$$Cov[B(t,T), F(t,T)] = (T-t)[\ln(T) - \ln(T-t)](\rho_{SF}\sigma_S\sigma_F - \sigma_F^2) \tag{13}$$

to give

$$\beta(t) = 1 + \frac{(T-t)[\ln(T) - \ln(T-t)](\rho_{SF}\sigma_S\sigma_F - \sigma_F^2)}{t\sigma_F^2} \tag{14}$$

From equation (14), it can be seen that as $t \to T, b \to 1$. As the period to expiration increases, i.e. $t < T$, the hedge ratio β depends increasingly on the terms $(\rho_{SF}\sigma_S\sigma_F - \sigma_F^2)$, which describes the covariance between the futures price and the basis price. This covariance has been shown to be negative previously in Castellino's paper, and hence the hedge ratio β will decrease as time to expiry increases. By allowing $t = 1$ and T to approach infinity, equation (14) is reduced to equation (5).

Despite this confluence of theory, the Ederington minimum variance ratio derivation method is limited in many ways by its use of simple OLS regression estimation. Simple OLS provides a very basic model that fails to accommodate a number of the characteristics of the underlying data. Apart from factors such as autocorrelation and heteroskedasticity, it also fails to take into account the well-documented time varying nature of futures contracts (which, as demonstrated by Castellino, introduces time varying bias issues to the speculative component). This will affect the calculation of the hedge ratio, and hence the effectiveness of the eventual hedge.

There has been ample study done to show that both spot and futures prices in the currency markets appear to follow a random walk, such that price changes are uncorrelated with historical price changes – leading to the finance truism "the past is not a good predictor of future earnings". It could be surmised, therefore, that the hedge ratios calculated from these prices should likewise follow a random walk. Malliaris and Urrutia (1991a) use the Dickey-Fuller test and the Lo-MacKinlay test to show that a series of Ederington minimum variance hedge ratios do in fact follow a random walk. If this is the case, then the concept of a constant hedge ratio is clearly flawed. A constant hedge ratio will be approximate at best, and is likely to become increasingly inappropriate as the time period to which it is applied increases.

Grammatikos and Saunders (1983) observe that the ordinary least squares regression is inappropriate over longer time periods as the hedge ratio derived may not be stable over time. This in turn may invalidate the R^2 measure as an appropriate measure of hedging effectiveness. They test for structural changes in the currency movements using dummy variables, such that

$$\Delta S_t = \alpha + \beta_1 \Delta F_t + \beta_2 (D_1 \Delta F_t) + \beta_3 (D_2 \Delta F_t) + \beta_3 (D_2 \Delta F_t) + \beta_4 (D_3 \Delta F_t) + u_t \tag{15}$$

where $D_1 =$ 1 for $t =$ 1/1976 to 12/1977

0 for all other t

$D_2 =$ 1 for t = 1/1978 to 12/1979

0 for all other t

$D_3 =$ 1 for t = 1/1980 to 6/1980

0 for all other t

If the hedge ratio is stable over time, then $\beta_2 = \beta_3 = \beta_4 = 0$, and $\beta_1 \neq 0$. However, this is a fairly inaccurate method for factoring in structural change, and may be subject to criticism for arbitrary period selection in specifying the location of "changes" in the series.

Viswanath (1993) examines the effects of spot-futures convergence on hedge ratio calculation under the assumption that the current basis contains forecasting information about the future spot and futures prices. Viswanath posits that as the spot and futures price converge at maturity, a model that incorporates the basis will allow the spot return to converge to the EMV ratio at maturity. Viswanath models this relationship as:

$$S_t = \beta F_t + \delta_s (F_{t-1} - S_{t-1}) + \varepsilon_t \tag{16}$$

where δ is some ratio that determines the amount of basis information at time $t-1$ that is incorporated into the estimated spot price at time t. This is essentially the EMV ratio with this added component reflecting the basis estimation of future prices. This approach is shown to be effective in some cases, minimising the variance of some of the commodities examined in the paper while having little effect on others.

De Jong, De Roon and Veld (1997) compare the ex-ante effectiveness of a full hedge, and three methods of hedge ratio calculation based on the EMV ratio, the Fishburn α-t model, and the Howard and D'Antonio(1984, 1987) Sharpe ratio[12] based model, which they call the H^* ratio. The H^* ratio attempts to maximise the risk-return trade-off, creating a portfolio more closely aligned to the Working (1953) view of hedging as speculation. Instead of focussing primarily on the risk minimisation potential of a hedge, as do the first two estimation methods, the Sharpe ratio incorporates a comparison of performance against a risk-free rate of return, and hence the optimal hedge from the Sharpe perspective should earn a profit. However, De Jong et al. find that the full hedge performs better than the ratio-based hedges, and that the H^* hedge significantly reduces the performance of the hedged portfolio and is never preferable. As a result, the H^* hedge has not been adopted in the literature and is not examined further here.

There are significant drawbacks to ordinary least squares hedge ratio estimation. Baillie and Bollerslev (1989a, 1994) have shown that spot and futures prices are non-stationary and cointegrated, which can lead to ratio misspecification if simple OLS regression models are used to estimate it. Kroner and Sultan (1993) observe that if the spot and futures rates are cointegrated, then the OLS regression is misspecified and requires the use of an error-correction model to overcome this problem, while Ghosh (1993a) shows that a smaller than optimal futures ratio is likely to be estimated when the cointegrating relationship is not incorporated into the estimation model. Lien (1996) further shows that the presence of cointegration between spot and futures prices is likely to lead to the ratio being misspecified. An error-correction model (ECM) can be used in place of the standard OLS model to capture the cointegrated nature of the spot and futures and the

[12] The Sharpe ratio is discussed in more detail in section 2.3

existence of unit roots in the time series. Engle and Granger (1987) proposed an error-correction model of the form:

$$\Delta S_t = \alpha_s + \theta_s z_{t-1} + \sum_{i=1}^{m} \gamma_{si} \Delta F_{t-i} + \sum_{j=1}^{n} \delta_{sj} \Delta S_{t-j} + \varepsilon_s$$

$$\Delta F_t = \alpha_f + \theta_f z_{t-1} + \sum_{i=1}^{m} \gamma_{fi} \Delta F_{t-i} + \sum_{j=1}^{n} \delta_{fj} \Delta S_{t-j} + \varepsilon_f \tag{17}$$

where z_t is a stationary linear combination of S_t and F_t, and the basis (F_t - S_t) is usually chosen for this task. Recent work on currencies such as that by Wu and Chen (2001) has indicated that an ECM is useful in exchange rate forecasting, and provides superior estimates to traditional random walk models. Work on currency hedging has also found support for ECM ratio estimation. Ghosh (1996) finds that the ratio derived using the ECM is significantly better than that derived using the Ederington minimum variance ratio when cross-hedging currencies, although this study is limited to major developed economy currencies in a single time period. Other studies have used the ECM model to hedge a variety of alternative financial instruments including stock market indices and commodities. Chou, Denis and Lee (1996) use the ECM regression developed by Myers and Thompson (1989), which extends the Engle and Granger model, to show that hedge performance is improved over the Ederington minimum variance ratio when used to estimate ratios for hedging the Hang Seng index. Other studies such as Wang and Sern Low (2003) and Yang and Awokuse (2003) implement enhanced ECM hedges using GARCH[13] frameworks, with the cointegrating ECM on stock indices and commodities respectively, noting superior performance. With significant evidence in its favour, the ECM ratio will be used in this thesis as an alternative minimum variance hedge ratio calculation method to the Ederington minimum variance ratio.

[13] Generalised Auto-regressive Conditional Heteroskedasticity – see page 25 for more detail.

As well as cointegration effects, exchange rate series are often observed to have heteroskedastic variances in the error terms, i.e. variances that change over time (Bollerslev, 1990), and this may be particularly evident in short run series. Engle (1982) shows that Generalised Auto-regressive Conditional Heteroskedasticity (GARCH) models can be used to correct for heteroskedastic time series. While some OLS estimation approaches adjust for heteroskedasticity by providing adjusted standard errors (White, 1980), the GARCH model provides a more comprehensive framework from which to study such time series. There are a number of variations on the basic GARCH model that have been used in the estimation of hedge ratios, however the evidence in their favour is inconclusive at best, and often negative. The technique was examined in some detail in the 1990s (see Lien and Tse, 2002, for a summary of this research) and there is little evidence to point conclusively in favour of using a GARCH model in preference to standard OLS regression. Kroner and Sultan examine the use of a bivariate GARCH error-correction model to estimate the hedge ratio *b*. The GARCH model allows the ratio to change as the risk changes over time, and find that GARCH error-correction model derived hedge ratios reduce the variance of the portfolio more effectively than the standard minimum variance hedge ratio.

While Lin, Najand and Yung (1994) likewise find in favour of the GARCH model over the OLS model, they note that as the duration of the hedge increases, the benefits from the GARCH model diminish. Lien, Tse and Tsui (2002) differ in their assessment of GARCH models, finding that the standard OLS hedge ratio outperforms the Bollerslev (1990) constant-correlation GARCH model when hedging using futures over a variety of assets including currencies. They conclude that GARCH models should not be used for hedging purposes. A comprehensive survey of the literature related to GARCH models and their use in hedge ratio estimation was performed by Lien and Tse (2002), who concluded that there was limited evidence to support an argument for the superior effectiveness of GARCH models. As the weight of evidence seems to point against the usefulness of the GARCH model, it will not be used in this thesis.

A risk averse investor may wish to limit their likelihood of loss. However if they are investing with the Working (1953) view of hedging in mind, then they also wish to maximise the upside potential of the hedge. Minimum variance ratio hedges traditionally attempt to keep the outcome at a defined level, where both upside and downside risk are treated as equally undesirable. All variance is considered bad, rather than just downside variance, and so a ratio that provides the minimum variance is regarded as optimal. In reality, many investors are happy to deviate from a defined value if the result is a profit, while few investors are happy with a large downside and the resulting loss. Fishburn (1977) discusses the idea that investors may be particularly averse to this downside risk and may wish to find a hedging strategy that minimises portfolio losses while still maintaining the potential for upside gains. Fishburn contends that the standard measure of risk, variance, does not typify investor's return preferences. Instead, investors typically have an ideal target return in mind, and the choice of portfolio is influenced by this target rather than the zero variance target assumed by a mean-variance framework.

Fishburn takes this concept and incorporates the assumption of heterogenous investor risk profiles into hedging theory, creating the foundations of the lower partial moment hedge ratio. Following on from the mean-variance portfolio selection theory popularised by Sharpe (1964), Lintner (1965) and Markowitz (1959), the concept of semivariance as a measure of risk, rather than the traditional variance measure, is defined by Markowitz (1959) as the variance of the return below some target return τ, where $\tau = 0$ when examining the problem of negative returns. When choosing a portfolio to minimise semivariance, the portfolio with the greatest positive skewness is selected. If a hedge is regarded as a portfolio selection exercise, then the lower partial moment hedge is that combination of futures and assets that creates a portfolio with the greatest positive skewness. The degree of skewness of the portfolio will be determined by the hedger's risk-return utility function. An extremely risk-averse investor will choose $\tau = 0$, such that no negative returns are acceptable (and hence this will be equivalent to the return preferences of a minimum variance hedge ratio).

The other decisive factor in the portfolio choice is the order of the lower partial moment. Fisher shows that there is a value, described in the paper as α but referred to here as n, which represents the degree of risk aversion of the investor toward large losses and is used to calculate the power of the lower partial moment. A normally downside risk averse investor selects $n = 2$, and hence uses a standard semivariance model. However, Fisher shows that a more or less downside risk averse investor may wish to choose some other value for n, which will reflect their preference for large vs. small return deviations. To incorporate n, the term "lower partial moment" is used, where $n = 2$ represents semivariance while other values of n describe other moments. The lower partial moment can be therefore be defined as :

$$LPM_n(R_\tau;F) = \int_{-\infty}^{R\tau} (R_\tau - R_p)^n \, dF(r) \tag{18}$$

where R_τ is the target rate of return for hedged portfolio return R_p with distribution function $F()$, and n is the n^{th} order lower partial moment of R_p, and is non-negative.

Equation (18) shows clearly that the lower partial moment is a function of the investor's degree of risk aversion, n, in failing to meet the target return R_τ. Hence an aversion to a large shortfall results in a large value of n, while a small value of n indicates a shortfall is of less concern. This may better reflect the preferences of an investor seeking an optimal hedging strategy, and may allow a solution that is more adaptable to individual requirements than minimum variance ratios. Both Eftekhari (1998) and Lien and Tse (2000) show that the optimal hedge ratio to minimise downside risk increases with the investor's sensitivity to downside risk. In other words, as the investor becomes more risk-averse, the optimal hedge ratio increases. This results in quite different ratios being implemented using the LPM technique than those of the EMV ratio technique.

Lien and Tse (2000) show that the lower partial moment can be obtained from the empirical distribution function:

$$l^*\left(R_\tau, n, R_p\right) = \sum_{R_P < R_\tau} \left(\frac{1}{N}\right)\left(R_\tau - R_P\right)^n \tag{19}$$

where R_p is the return on the hedged portfolio,

and N is the number of observations.

There are two competing methods of ratio derivation that may be used in practice. The simplest technique is an iterative one, such as that outlined by Eftekhari (1998). An iterative loop is executed, which estimates the return on the portfolio for every possible hedge ratio between some maximum and minimum (eg. -2 to 2) with defined increments (eg. 0.00001). The ratio that minimises the lower partial moment according to the equation:

$$LPM = \frac{1}{T}\sum_{t=1}^{T}\left(\min[0, R_P - R_\tau]\right)^2 \tag{20}$$

is selected as the hedge ratio.

This technique, while simple, is time-consuming and can take a considerable time to run for large samples. An alternative estimation technique is kernel estimation, and is explored by Lien and Tse (2001). Lien and Tse find no significant difference in the estimation methods, and note that kernel estimation is also time-consuming. Significant improvements in computer power mean that estimates, while still time-consuming, are relatively quicker than in the past, and an iterative technique is used here to generate lower partial moment estimates. This technique, apart from greater resolution in iterations, also contains some enhancements that make the algorithm superior to that used by previous authors. More details for this can be found in Chapter 8.

A significant benefit of the lowest partial moment ratio, other than the ability to compensate for investor heterogeneity, is that it makes no assumptions about return distributions (Eftekhari, 1998). A distribution with non-normal errors, such as that often observed in currency returns, will not bias the estimation model as may be the case with OLS regression. The derivation of a lower partial moment hedge ratio enables the return characteristics of the portfolio to be implicitly addressed while estimating an optimising hedge ratio.

2.1.2 Options vs. Futures

The selection of an appropriate derivative instrument is vital when implementing a hedge. Options and futures can both be used to produce a hedge, and are exchange tradeable and widely available. Forwards, swaps and other custom-built derivatives may also be used, and are supplied over-the-counter by merchant banks and other financial service providers. Forwards and futures, while being similar in nature, differ particularly in that a forward contract is typically used when a hedger anticipates the delivery of the commodity underlying the contract, while futures contracts are usually offset by entering an opposite but equal position before expiry. A forward contract can also be tailored to the precise needs of the hedger in terms of size, time to expiry, commodity quality and delivery location. A futures contract is a standard exchange-traded derivative that may only approximate the exact needs of the hedger. However, as futures are exchange-traded and can be closed out at will, they provide a flexible and accessible alternative. This thesis will focus on exchange-traded instruments, specifically the futures contract.

Marshall (2000) found that 20% of East Asian multinational companies surveyed used futures to manage exchange rate risk, while 45% used options. This preference for options as the exchange-traded derivative of choice is interesting, as empirical research tends to point to futures as the optimal hedging solution. Chang and Shanker (1986) compared the use of options and futures as hedging instruments, looking specifically for redundancy. It is possible to replicate a futures contract by purchasing a call option and selling a put option, while there are elements of an option that cannot be replicated by futures contracts. In one sense, then, the futures contract could be said to be redundant.

Once transaction costs have been incorporated into their model, they show that currency futures outperform currency options.

Interestingly, Chang and Shanker note that options may be used to hedge contingent transactions, and as such have a use that futures contracts are unable to replicate. However, this argument is refuted by a number of researchers including Lien and Tse (2002). Battermann, Braulke, Broll and Schimmelpfennig (2000) further demonstrate theoretically that an exporting firm exposed to exchange rate risk will prefer futures to options as the use of futures makes the income flow deterministic, while the options are always subject to an element of uncertainty. They note also that the income derived from the futures hedge should exceed that of the options hedge under the assumptions made in their research. Lien and Tse (2001) compared the effectiveness of currency futures and options products when used to minimise downside risk, as defined by the lower partial moments measure. As discussed previously, in this instance downside risk is measured as a function of the shortfall of the portfolio from the target return. A hedge ratio is determined that minimises these lower partial moments, and the performance of this hedge is compared to the minimum variance hedge. They conclude that in the majority of cases, the currency futures provide a more effective hedge than the currency options. They find that options outperform futures only when the individual hedger has a high level of risk tolerance, and will not differentiate between large and small losses.

The transaction costs incurred in the process of making the hedge are often overlooked in empirical research. Lien and Tse (2002) note that when transaction costs are taken into account, the higher transaction costs of options are a significant deterrent to using them as a hedging vehicle. As a result, there is generally believed to be a preference for hedging using futures contracts. However, in a study of the exchange rate risk hedging activities of one US company, Brown (2001) found that options were the preferred instrument due to accounting treatment and pricing concerns. While it is noted that the choice of hedging instrument must take transaction costs and taxation issues into account, and so the preference of the individual hedger may differ from that determined by empirical research, the focus of this thesis is on the use of futures as hedging instruments.

2.2 Cross-Hedging

When the option to directly hedge a spot exposure is unavailable, an alternative strategy is to use a cross-hedge. A cross-hedge is the creation of a portfolio containing the asset (spot) and a futures contract in an asset that differs in location, type, grade, or maturity date. Anderson and Danthine (1981) examined the use of the cross-hedge through a theoretical framework, and showed that the cross-hedge could be used effectively in situations where no direct hedge existed, and that the optimal cross-hedge ratio could be calculated in the same manner as for an optimal direct hedge ratio. This cross-hedge will tend to reduce a lower proportion of the risk inherent in the spot exposure than a direct hedge, however there are many circumstances in which it may be difficult to create a portfolio with a direct hedge. This is frequently the case in many areas of foreign exchange, where exchange-traded markets for currency futures contain a limited subset of global currencies.

Cross-hedges have the advantage of greatly expanding the alternatives available to a hedger, giving them additional options when selecting hedged portfolios (Eaker and Grant, 1987). This is particularly salient in countries with less-developed financial markets. Emerging markets, while showing the potential for large returns (Harvey, 1994), are also much riskier markets than the more established and better regulated “western” markets. Emerging markets such as those of East Asia have less developed financial markets than more developed “western” economies, and it is less likely that liquid markets in currency derivatives exist, if they exist at all. The derivatives markets of East Asia lack liquid exchange traded currency derivatives (Commonwealth of Australia, 1999), leaving investors with few opportunities to implement direct hedges. The frequency of crises in emerging markets are also far greater, and the last decade has been marked by a number of currency and other financial market crises in emerging markets such as Mexico (1994) and East Asia (1997). Any exposure to these markets would make a hedging strategy seem prudent. However, as most of these markets have relatively undeveloped derivatives markets and there are no exchange-traded derivative products available in foreign derivatives exchanges such as the Chicago Mercantile Exchange and the Sydney Futures Exchange, the only hedging solution available using exchange-traded products is a cross-hedge based on another asset and/or contract. It is also less likely that there will be opportunities to create alternative hedges through borrowing or lending the currency or through the use of forward contracts.

Eaker and Grant use the Ederington minimum variance hedge ratio to examine the effectiveness of cross-hedges on a variety of less-developed European currencies (the lira, drachma and peseta) and the South African rand, using futures in a variety of developed economy currencies (the pound, Canadian dollar, mark and yen). They find support for the use of ratio cross-hedges, and show that while a cross-hedge is less effective that a direct hedge in terms of risk reduction, the cross-hedge was still effective in reducing risk. A direct hedge will always be preferable to a cross-hedge, but when no direct hedge is possible, the currency cross-hedge may be an effective way to reduce the risk on a currency portfolio. Eaker and Grant find that the effectiveness of the cross-hedge corresponds to the degree of integration of the country into the European economy.

Further, a cursory look at IMF trade relationship rankings showed that the trade relationship between the two countries in the cross-hedge was a good indicator of the effectiveness of the hedge – countries with a close trading relationship provided more effective cross-hedges. This indicates that the more economically related the assets in question are, the more effective the cross-hedge is likely to be. Additional support is found by Glenn and Jorion (1993), who show that an international portfolio hedged against currency risk offers a better risk-return ratio than an unhedged portfolio.

Aggarwal and Demaskey (1997) followed up on the 1990's enthusiasm for investment in emerging markets by investigating the use of cross-hedging to hedge an emerging market currency exposure in the Asian region. During the early 1990's, the Asian markets experienced a period of rapid growth and were a destination for much foreign capital – indeed, they assert that Asia attracts "the largest proportion of cross-border investments"[14]. Aggarwal and Demaskey examine the effectiveness of hedged portfolios of a number of East Asian countries (Hong Kong, South Korea, Singapore, Taiwan, Indonesia, the Philippines and Thailand), cross-hedged against the Japanese yen, British pound, Canadian dollar, German mark and Swiss franc. They investigate the use of full and Ederington minimum variance hedges in both options and futures, and find that ex-ante hedged portfolios exhibit an improvement in performance over unhedged

[14] Aggarwal and Demaskey (1997), p. 782

portfolios. They also show that the Japanese yen futures contract provides a superior hedge for Asian currencies to that of the "western" economy currencies, which may indicate that there are closer economic linkages between East Asia and Japan than East Asia and the "west". Indeed Aggarwal and Demaskey see the superiority of the Japanese yen hedge on the Asian currencies as evidence of an emerging yen bloc.

Cross-hedges can be formed using any alternative derivative that has some relationship with the asset being hedged, and so currency hedging is not limited to alternative currency derivatives. Commodity derivatives have also been used to cross-hedge currencies, but with little success. Eaker and Grant (1987) use gold futures to cross-hedge the currencies examined, but find that it performs poorly compared with currency cross-hedges. Even in the case of the South African rand, which the authors speculate would be the most likely of the currencies to result in a successful gold cross-hedge, gold futures eliminate only a small amount of risk compared with the performance of the currency hedges. Bennet (1990) also looks at commodity futures in cross-hedges, motivated specifically by the desire to hedge currency exposures for "less developed countries" (as emerging markets were previously known). However, Bennet also finds no support for the use of commodity futures to hedge currencies, and finds that the commodity futures hedges actually increase risk compared to unhedged portfolios. Eaker and Grant also found this to be the case in six of the nine gold/currency hedges they examined. It can be concluded that there is little evidence to support the use of commodity-currency cross-hedges, and this thesis will focus on currency cross-hedges.

2.3 Hedged Portfolio Effectiveness Measurement

The choice of analysis method for determining the effectiveness of a hedge is a critical issue, and one that is determined by the theoretical approach taken to hedging. Indeed, Yau, Savanayana and Schneeweis (1990) observe that the choice of return measure will impact significantly on the results of hedge effectiveness measurement, and the selection of the hedge effectiveness measure should be based on the personal utility function of the hedger. The motivation of the hedger should be considered in the selection of the method used to measure hedge effectiveness, and should be grounded in the appropriate theory.

In traditional hedging theory, the "protection" aspect of hedging dictates that the primary purpose of a hedge is to protect the asset value of a portfolio. Early studies of hedging such as that of Graf (1952) simply compare the unhedged portfolio return R_S to that of the portfolio return R_P, and determine effectiveness based on the magnitude of the respective returns. As long as the hedged portfolio appreciates (devalues) more (less) than the unhedged portfolio, the hedge is deemed to be successful. Hence Graf uses the simple measure:

$$Effectiveness = \frac{R_P - R_S}{abs(R_S)} \tag{21}$$

However, Working (1962) challenged the notion that the motivation to hedge was one of "protection", and introduced the concept of the hedge as a profit making transaction or "speculation on the basis". Assuming that the return on a hedge was determined by the basis, Ederington (1979) took a portfolio theory approach, and introduced the concept of R^2 as a measure of risk reduction and therefore portfolio performance, such that

$$R^2 = \frac{\sigma_{SF}^2}{\sigma_S^2 \sigma_F^2} \equiv \rho_{SF}^2 \tag{22}$$

where σ^2_{SF}, σ^2_S, σ^2_F are the portfolio, spot and futures variances respectively. The Ederington R^2 measure is effectively the coefficient of determination calculated from the hedge ratio estimation regression (equation (9)) and this measure of ex-post hedge effectiveness has been widely adopted in subsequent research, despite misgivings about the use of this ratio when using alternative models for minimum variance hedge ratio estimation (Herbst, Kare and Caples, 1989).

However, the R^2 measure is only a measure of risk, and takes no account of the profitability of a hedge. Indeed, Castellino (1992) asserts that the use of the minimum variance ratio is contrary to the Working view of a hedge as "speculation on the basis" as it serves no profit-making role at all, and is oriented solely toward minimising risk. Howard and D'Antonio (1984) point out that this orientation precludes the R^2 measure from being a suitable universal indicator for hedging effectiveness in a real-world scenario, where hedgers are likely to have a profit motive as well as a risk-reduction motive. Further, when determined from the regression equation, it measures only risk reduction in-sample. In a real world scenario, the out-of-sample performance of the hedge is far more important than in-sample performance, as it is not possible to estimate a hedge ratio and implement a hedge over the same period in practice.

Instead, another concept from portfolio theory, the Sharpe ratio, can be used to fully integrate the concepts of risk and return in a measure of hedge performance. The Sharpe ratio (SR) is based on work by Sharpe (1994) on the capital market line. If the ex-post capital market line is defined as

$$R_P = R_f^* + \frac{\sigma_P}{\sigma_m}\left[R_m - R_f^*\right]$$

(23)

where R_f^* is the risk free rate of return,

R_m is the market return,

and R_P is the return on the portfolio.

If the capital market line holds, then equation (23) can be rearranged to show that:

$$\frac{R_P - R_f^*}{\sigma_P} = \frac{R_m - R_f^*}{\sigma_m}$$

(24)

The Sharpe ratio is then defined as:

$$SR_P = \frac{R_P - R_f^*}{\sigma_P}$$

(25)

This ratio allows portfolios to be compared for relative efficiency. A higher Sharpe ratio indicates a better return per unit of variance, and this enables portfolios to be easily compared to determine investor preference. The Working (1953) view of the hedge as a speculative investment is borne out in the assessment of the hedge using the Sharpe ratio, as it rewards the hedge for its performance as an investment portfolio, and the portfolio view of hedging is satisfied as it incorporates both risk minimisation and return performance in the calculated ratio.

To return to traditional hedging theory, if the object of the hedge is to reduce risk rather than to invest or speculate, then a ratio that seeks to compare the hedge with the risk-free rate of return may be less relevant that a direct comparison of the performance of the unhedged portfolio and that of the hedged portfolio. Assuming the decision to invest and receive the foreign currency has already been made, the Sharpe ratio is less important as a measure of performance as the investor is concerned not with the risk-free rate, but with the performance of the unhedged portfolio versus the hedged portfolio. In this case, it may be preferable to compare the Sharpe ratio of the hedged portfolio with that of the unhedged portfolio, given by:

$$SR_S = \frac{R_S - R_f^*}{\sigma_S} \tag{26}$$

The comparison of hedged and unhedged portfolio performance enables the hedger to see if they have in fact improved the return per unit of variance risk. This thinking led Howard and D'Antonio (1987) to combine equation (25) and equation (26) to derive a measure of hedging effectiveness *HBS*. Essentially Howard and D'Antonio propose that hedge effectiveness be measured by

$$HBS = SR_P - SR_S \tag{27}$$

where SR_P is the Sharpe ratio of the hedged portfolio, while SR_S is the Sharpe ratio of the unhedged (spot) portfolio. This they restate as:

$$HBS = \frac{R_f^* + SR_P\sigma_S - R_S}{\sigma_S} \tag{28}$$

In the case where the hedge is implemented primarily to protect the value of the investment, this measure may give a more appropriate measure of hedge performance. It is also allows a simple and rapid assessment of the relative performance of the two portfolios. If the *HBS* value is zero, it indicates that there is no difference in return per unit of risk between the hedged and unhedged portfolio. A negative *HBS* value indicates that the unhedged portfolio shows a higher return per unit of risk than the hedged portfolio, and a positive value shows that the hedged portfolio shows a relatively higher return per unit of risk. For an investor to prefer the hedged portfolio, the *HBS* value should be positive.

2.4 Time-Varying Nature of Hedge Ratios

Initially, hedge ratios were assumed to be time-invariant and hedge ratios were often calculated over long durations, such as years (Brown, 1985). While most early studies were limited to in-sample analysis of hedging effectiveness (eg. Ederington, 1979), studies such as Eaker and Grant (1987) noted that the Ederington minimum variance hedge ratio would change between estimation periods. If a sample of observations is split in two, the optimal hedge ratio estimated for the second half of the sample typically differs noticeably from that estimated in the first half of the sample, and both will differ to a hedge ratio estimated over the full period. This indicates that hedge ratios are time varying, an idea developed further by Cecchetti, Cumby and Figlewski (1988) who show that as the joint distribution of spot and futures price changes is time variant, so too is the estimated hedge ratio. Malliaris and Urutia (1991) also observe that their moving window analysis technique (discussed further in this chapter) generates different hedge ratios in each sub-period to that generated for the overall period, indicative of a time-varying nature. Models such as ARCH and GARCH models have been proposed that accommodate time-varying return covariance matrices, however these do not seem to have improved performance. For instance, Myers (1991) uses the GARCH model to estimate optimal hedge ratios, but finds that it does not perform significantly better than other, time invariant models.

The construction of a hedge requires two basic sets of calculations: the estimation of the hedge ratio over some initial period, T_1 (hereafter known as the hedge ratio estimation period), and the subsequent use of that ratio to form a portfolio over a second period, T_2 (hereafter known as the hedge implementation period). In the ex-post, or one period, method these two periods are identical (i.e. $T_1 = T_2$) and performance is assessed in-sample (see for example Ederington, 1979). However, for more practical and realistic ex-ante performance analysis, there are several approaches that may be taken when selecting the hedge ratio estimation period. Firstly, a single sample period can be used that includes a hedge ratio estimation period and a hedge implementation period. The hedge ratio estimation period takes up a pre-selected number of observations, while the rest are used as the hedge implementation period and the assessment of hedging effectiveness is performed over this implementation period. This technique is typically used in early studies such as Dale (1981), although later studies such as Ghosh (1996) also use this technique. However, the time-varying nature of hedge ratios is unacknowledged by this method, and ratios that are unstable over time become particularly problematic if the hedge implementation period has a long duration. Instead, a sequential approach can be taken such as that used by De Jong, De Roon and Veld (1997). This method involves dividing the time period into sections, none of which may overlap – so a 30 day hedge ratio estimation period is followed by a 30 day hedge implementation period, followed by second 30 day hedge ratio estimation period, etc.

Figure 2-1 illustrates this concept. The first hedge ratio estimation period runs for 30 days from March 1 to March 30. The hedged portfolio is then formed and analysed over the subsequent 30 days, from March 31 to April 29. The next hedge ratio estimation is performed over the 30 days from April 30 to May 29, and the next hedged portfolio is formed from May 30 to June 29.

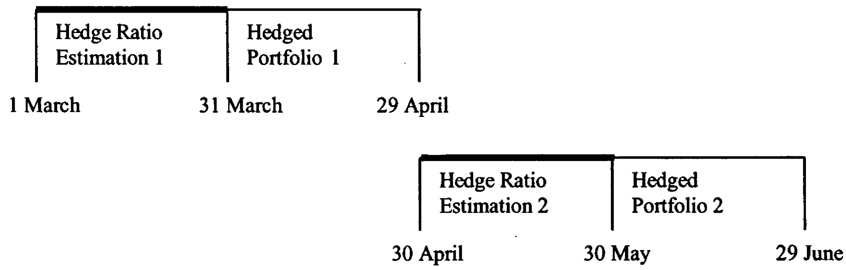

Figure 2-1 : Timeline for sequential time period analysis

Alternatively, a sequential moving window approach can be used, where the second hedge ratio estimation period starts on the same day as the first hedge implementation period. This concept is illustrated in Figure 2-2.

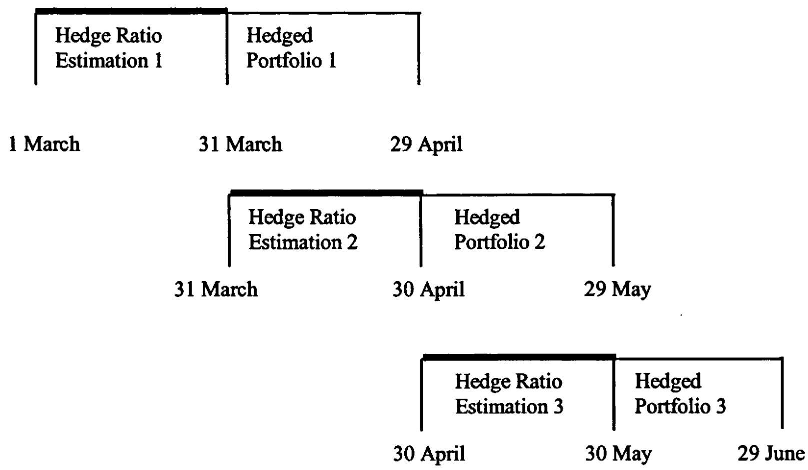

Figure 2-2 : Timeline for sequential moving window analysis

In both methods, the choice of sampling periods may influence the results, as they are prone to arbitrary period selection. While some periods may indicate effective performance, the selection of other periods within the sample (e.g. starting the hedge ratio estimation period on March 10 instead of March 1) may indicate otherwise. If arbitrary period selection is to be avoided, it is preferable to use a true moving window approach that encompasses all possible period selections within the sample of observations.

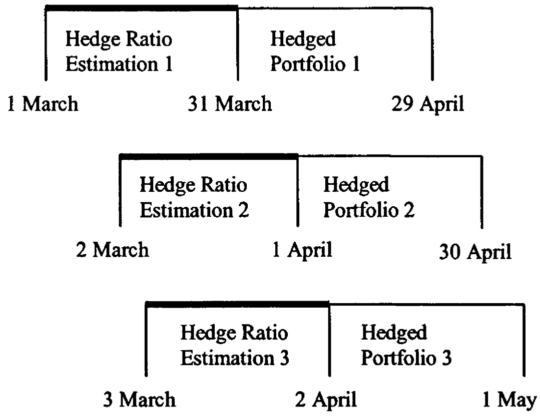

Figure 2-3 : Timeline for true moving window analysis

A true moving window approach is illustrated in Figure 2-3. In this method, every possible combination of 30-day periods over the sample of observations is included. Empirical studies often employ the true moving window approach to create time-varying hedge ratios, such as Grammatikos and Saunders (1983), who describe it as the "overlapping regressions procedure", and Malliaris and Urrutia (1991a) who call it the "moving window regression procedure". The true moving window approach will be used throughout this thesis to minimise possible biases arising from arbitrary period selection.

2.5 Additional Considerations

While most studies use price changes as the basis for calculation of minimum variance ratios, there has been some discussion in the use of price levels as a basis for ratio calculations. However, the unit root properties of currency data mean that levels will be non-stationary, while price changes are difference stationary by nature. Hill and Schneeweis (1981) compare the use of price levels versus price changes when calculating hedge ratios and hedging effectiveness for foreign currency hedging using futures products. They observe that spurious correlation could exist between spot and future price levels. This casts doubt on the appropriateness of price levels to calculate ratios based on regression models, which tend to show residuals with high degrees of autocorrelation. Hill and Schneeweis show that the use of price level data results in hedge ratios that are significantly higher than those calculated using price changes. Price change data will be used throughout this thesis to calculate hedge ratios as per their analysis.

A number of studies examine the issue of the optimal length of the hedge ratio estimation period. If hedge ratios are assumed to be stable over time, it follows that the longer the hedge ratio estimation period, the more accurate the resulting hedge ratio will be. Alternatively, if hedge ratios are not stable, then a shorter period will be preferable[15]. Both Hill and Schneeweis (1981) and Grammatikos and Saunders (1983) have highlighted this as an important factor to consider when determining an appropriate hedge ratio estimation period. However, Malliaris and Urrutia (1991b) find that the length of the hedge ratio estimation period is not a major influence in the subsequent performance of the hedge, but rather that the length of the hedge implementation period is the most important factor in hedge implementation performance. Malliaris and Urrutia implement Ederington minimum variance ratio hedges for several major currencies and compare the performance of ratios applied over one week hedge implementation periods to those applied over four weeks. During hedge ratio estimation, R^2 values improve when the duration of the hedge ratio estimation period increases. However, when hedges are implemented out-of-sample and their

[15] See section 2.4 for further discussion of hedge ratio stability.

portfolio returns are compared, it is found that a shorter implementation period results in better performance than a longer one[16].

Other studies have supported this result. Benet (1992) investigates the influence of the hedge ratio estimation period duration when applied specifically to exchange rate risk minimising cross-hedges, and observes that a longer hedge period (of 12 weeks) results in a more effective ex-post hedge than a shorter period (4 weeks). However, as previously noted, it is not possible to implement an ex-post hedge, and measures of in-sample effectiveness need to be contrasted with out-of-sample performance. Benet comments that while the estimation process may result in seemingly high R^2 values, ex-ante hedges often result in significantly lower risk-reduction performance[17], and concludes that there seems to be no real relationship between the length of the ratio estimation period and the risk-reduction performance of implemented hedges. Benet instead finds that an increase in the timeframe used to estimate the hedge ratio does not improve the performance of the implemented hedge, but rather results in a decline in hedge performance. Benet attributes this to hedge ratio instability, which impacts significantly on the effectiveness of a cross-hedge, and this instability increases as the hedge implementation period increases in length. This result indicates that a rebalancing strategy should outperform one which requires the hedge ratio to remain constant.

There is also evidence that, as the duration of the hedge implementation period increases, the optimal hedge ratio approaches unity. Both Geppert (1995) and Chen, Lee and Shrestha (2003) find that the optimal minimum variance hedge ratio approaches 1

[16] Note that to keep performance measures relatively consistent between hedge ratio estimation and hedge implementation periods, those returns closest to zero are regarded as most effective in this study.
[17] Benet (1992) p. 166

as the hedge implementation period increases in duration, and conclude that for long duration hedges, a full hedge will offer the optimal solution.

Drawing on the work discussed above, this thesis will estimate hedge ratios over 60 trading day periods. This window length has been chosen as it enables error-correction model ratios to be estimated (a 30 trading day window often proves too short to effectively estimate ratios) and incorporates a reasonable amount of prior-period information. Hedges will then be implemented over subsequent 30 day periods.

2.6 Correlation and Cointegration

Baillie and Bollerslev (1989b) note that "a general consensus has emerged in recent years that many macroeconomic time series ... can be characterised by a stochastic trend model ... similarly, it has long been recognized that many financial time series, such as foreign exchange rates, are nonstationary"[18]. It is well established in the literature that exchange rates are difference stationary processes, they contain unit roots, and exhibit time-dependent heteroskedasticity. Returns are also generally found to exhibit leptokurtosis (fat tails), and Hsieh (1988) concludes that this is caused by time-varying means and variances in the return series. Hsieh also finds that foreign exchange returns typically contain little serial correlation. Studies such as Liu and He (1991), however, have found evidence of serial correlation in exchange rate series, so some argument exists as to whether all of Hsieh's conclusions are strictly correct. Further, Hsieh focuses on floating, highly liquid currencies. Those currencies found in emerging markets, with managed exchange rate regimes and turbulent economic conditions, may not behave in such an predictable manner.

[18] Baillie and Bollerslev (1989a), p. 167

There has been little work published on the topic of currencies of developing countries in the Asian region, although the increasing level of interest in emerging markets has seen more work published recently. Typically, work focuses on the Japanese Yen, and includes that of Rana (1981), who analysed monthly observations of a group of Asian currencies including those of Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand over two periods: 1967-1971 (when all of these currencies were pegged), and 1973 – 1977. An analysis of skewness and kurtosis finds that the currencies exhibited excess kurtosis over the second period, implying non-normal distributions when the pegs were lifted.

Floating currencies are generally believed to be best modelled as random walk processes. The general structure of a random walk process can be described as

$$x_t = x_{t-1} + \varepsilon_t \tag{29}$$

where $\varepsilon_t \sim (0, \sigma^2)$ and is uncorrelated. Random walk processes have two major characteristics: they contain a unit root, and they have uncorrelated increments. Hence many studies of the behaviour of exchange rates seek to first disprove the hypothesis that the series is best characterised by a random walk model. For example, Corbae and Ouliaris (1986) use a variety of tests to demonstrate that they are unable to reject the null hypothesis that the exchange rates studied follow a random walk. Liu and He (1991) find evidence to reject the random walk model based on a Lo and Mackinlay (1988) variance ratio test that is robust to heteroskedasticity, and propose that while the random walk model holds, it may be rejected due to positive serial correlation in weekly exchange rate data. This implies that exchange rates may be non-stationary, and indeed subsequent work has indicated that this is the case more often than not.

Heteroskedasticity (Hsieh, 1991) and/or autocorrelation (Liu and He, 1991) are often a feature of exchange rates. As a result, the use of simple OLS regression models to analyse currencies may incorrectly interpret a null hypothesis, resulting in the hypothesis being accepted too often for a given level of significance. Particularly, when using regression analysis (such as in the case of the Ederington minimum variance model) a spurious regression may result when one non-stationary time series is regressed against another. Granger and Newbold (1974) show when regressing non-stationary time series against one another, the series should be differenced to become stationary before being regressed or misleading results will be obtained. Further, Hsieh (1991) states that OLS regression models should be adjusted for heteroskedasticity when used in currency analysis.

2.6.1 Unit Roots

If a time series contains a unit root, then it can be identified as non-stationary. Much literature examines the presence of unit roots in the foreign exchange rates of countries both developed and developing, and the identification of a unit root is generally regarded as the first step when analysing exchange rates. If exchange rates are characterised as unit root processes, then any shock to the exchange rate has a lasting effect on the system. However, while unit root tests can provide important information about the nature of exchange rates, the results of these tests may be inaccurate where structural breaks exist. This is particularly likely over periods of financial crisis, such as the crash of Wall Street in 1987 and the East Asian currency crisis of 1997. The presence of structural breaks in the data are likely to bias unit root tests such that a unit root hypothesis may be accepted inappropriately (Brooks and Rew, 2002). This may then cause errors when using cointegration models based on assumptions of nonstationarity of time series. Under traditional unit root tests it is easy to reject the unit root hypothesis erroneously, and in the 1990s much work was done to find successful tests of the unit root hypothesis that accommodated structural breaks (Zivot and Andrews, 1992, Perron and Vogelsang, 1992, Park and Sung, 1994).

2.6.1.1 Dickey Fuller and Unit Root Testing

Nelson and Plosser (1982) are generally credited with the proposal that most economic time series follow a random walk process, and are therefore nonstationary and contain a unit root.

The Dickey Fuller (1979) test for unit roots is premised on the time series taking one of the following forms:

1. $\Delta y_t = \gamma y_{t-1} + \varepsilon_t$
2. $\Delta y_t = a_0 + \gamma y_{t-1} + \varepsilon_t$
3. $\Delta y_t = a_0 + \gamma y_{t-1} + \beta t + \varepsilon_t$

(30)

where y_t is a time series, with intercept a_o, trend term y_{t-1} and white noise term ε_t. Equation (30.1) is based on the random walk model of equation (29); equation (30.2) contains an intercept; while equation (30.3) contains and intercept and a trend. Dickey and Fuller propose that a time series can be tested for a unit root using the equation that best describes the nature of the series, against a null hypothesis $\mathrm{H}_0 : \gamma = 0$ i.e. that the series contains a unit root. Critical values are then used to determine if the null hypothesis can be rejected. MacKinnon (1991) generated a more complete set of test statistics which are now widely used, as they are throughout this thesis. A significant assumption of the Dickey-Fuller unit root test is that of *iid* errors. As noted by Hsieh (1988), currencies do not typically exhibit *iid* characteristics. The standard Dickey-Fuller test, therefore, is not a good test for currency data. Instead, the Augmented Dickey-Fuller (ADF) test can be used, which seeks to rectify problems associated with this assumption. Equation (30.3) is modified to include a lag term to capture the effects of serial correlation, and is written as:

$$y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{k-1} \theta_i \Delta y_{t-i} + \varepsilon_t \tag{31}$$

where again γ is used to test for a unit root with a null hypothesis of $H_0 : \gamma = 0$. However, problems may arise with the estimation of the appropriate lag length for the model. In the case of currency data, the exact specifications of the model are unknown, and so an approximation is often made. Likewise, the ADF statistic aims to incorporate the impact of serial correlation in the error terms. However, the ADF technique may not accurately specify the series when the period examined contains some structural break or shock, such as the East Asian currency crisis, which may lead to the null hypothesis failing to be rejected. Papell (2002) shows that when using the ADF test on univariate real exchange rates, the null is rarely rejected, which may indicate a shortcoming in the ability of the test to accurately characterise data over short time periods.[19]

2.6.1.2 The Phillips-Perron Statistic

Phillips and Perron (1988) developed a non-parametric test (PP) based on the Dickey-Fuller test that eases some of the restrictions on the error term of the model. The test allows the errors to be weakly dependent and heterogeneously distributed. Like the

[19] Papell (2002) p. 52

ADF test, the PP test is now used regularly used in currency analysis. The statistic works under a similar premise as the ADF statistic, with the test defining cases such that

1. $\Delta y_t = \gamma y_{t-1} + \hat{u}_t$

2. $\Delta y_t = a_0 + \gamma y_{t-1} + u_t^*$

3. $\Delta y_t = a_0 + \gamma y_{t-1} + \beta(t - n/2) + \tilde{u}_t$

(32)

where n is the sample size, and $\hat{u}_t, u_t^*, \tilde{u}_t$ are stationary ARMA processes with time-dependent variables. As with the ADF test, the PP test has a null hypothesis of a unit root. Baillie and Bollerslev (1989a) used the PP test to show that foreign exchange data can be characterised as *I(1)* processes. The PP test has been used since then in studies such as Granger, Huang and Yang (2002), Anoruo, Braha and Ahmad (2002) and Aggarwal and Mougoué (1996), where the test is used in conjunction with the ADF test to verify the presence of unit roots in exchange rates.

2.6.1.3 Other Methods

Perron and Vogelsang (1992) propose a set of statistics that may be used to test the unit root hypothesis in the presence of structural change. Based on earlier work by Perron, two tests were considered: the additive outlier model (AO) that modelled an instantaneous change in the series, and the innovational outlier model (IO) which modelled a gradual change in the series incorporating a transitional period. Perron and Vogelsang use four techniques to determine the number of lags to be incorporated into the model, and conclude that the most effective lag selection method is to test the significance of the last included lag, working backwards from some maximum value

k_{max}, until it satisfies a 5% critical level t-test. This method has been used by Granger et al (2000).

Park and Sung (1994) offer an early test for unit roots in series with structural breaks. While the focus of this study is on macroeconomic data, the authors note that it is particularly applicable to time series widely held to contain structural breaks, such as exchange rates. The purpose of the model is to eliminate the dependency of previous unit root tests on a predefined breakpoint, and hence the biases that arbitrary period selection may introduce into the test. The model is based on the generalised least squares regression corrected for heteroskedasticity, with a weighting given to the pre- and post-break periods that are inversely proportional to the size of each sub-sample (i.e. a longer sub-sample gets a lower weighting). Park and Sung note that this gives an effect similar to the heterogeneity correction made by the GLS model. While this is notable work, it has not been widely used. Instead, the Zivot and Andrews (1992) test has become a more established test of the unit root hypothesis in series containing structural breaks.

2.6.1.4 Zivot and Andrews Statistic

Zivot and Andrews (1992) derive an alternative statistic that allows the ADF test to adjust for structural breaks in the data. Based on Perron and Vogelsang (1992), the Zivot and Andrews (ZA) method avoids the dummy variable problem of assumed perfect information, where the dummy variable is set depending on the point at which the structural break is believed to occur. The regression model used is the level shift with trend model, as per Granger et al (2000), such that:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta DU_t(\lambda) + \sum_{i=1}^{k} \theta_i \Delta y_{t-i} + a_t$$

(33)

where $DU_t(\lambda)$ = 1 for $t > T\lambda$,

= 0 otherwise

and $\lambda = Tb/T$ with Tb being the point of the structural break.

This method minimises the adverse consequences of arbitrary period selection through visual inspection by automating the positioning of the structural break according to empirical assessment. Instead, the regression is run through a series of iterations to determine the most likely break based on the value of the coefficient γ that generates the minimum t-statistic, and hence gives the least support for the unit root. This form, when tested against macroeconomic time series originally documented in Perron (1989), finds less evidence for the rejection of the unit root hypothesis in the examined series than is found when analysed using the predetermined breakpoint method. The number of lag terms are determined empirically based on the significance of the coefficient θ_i, working backwards from a maximum lag count of 12 as per Perron (1989). The appropriate number of lags is determined to exist when the value of i is chosen such that the t-statistic of θ_i is greater than 1.6 in absolute value, and the statistic for θ_{i+n} for n>0 is less than 1.6.

The success of the unit root hypothesis is determined using critical values generated for the value of λ estimated in each case. The Zivot and Andrews test has been adopted by a number of studies into macroeconomic series containing structural breaks. Alba and Papell (1995) use the Zivot and Andrews test and several other techniques to examine trend breaks and unit roots in the real GDP data of nine emerging East Asian countries. They compare the ADF test with the ZA test and find that the ADF test fails

λ	1%	5%	10%
0.1	-4.27	-3.65	-3.36
0.2	-4.41	-3.80	-3.49
0.3	-4.51	-3.87	-3.58
0.4	-4.55	-3.94	-3.66
0.5	-4.55	-3.96	-3.68
0.6	-4.57	-3.95	-3.66
0.7	-4.51	-3.85	-3.57
0.8	-4.38	-3.82	-3.50
0.9	-4.26	-3.68	-3.35

Table 2-1: Zivot and Andrews Calculated t-Statistics

to reject the unit root hypothesis for only 4 of the18 series tested. The ZA test, in comparison, rejects the unit root hypothesis for the majority of the series. Alba and Papell note that this is a stark contrast to the results for OECD countries, where previous studies have found little support for the rejection of the null hypothesis of a unit root. The structural breaks are attributed to government reforms, and the rejection of the unit root hypothesis in the Asian data is consistent with Alba and Papell's predictions.

The Zivot and Andrews test has also been used in studies of East Asian exchange rates. Granger, Huang and Yang (2000) use the ZA test to characterise daily East Asian exchange rate data over the period 1986 – 1998, a period that will include any structural breaks that may have occurred during the 1997 currency crisis. They reject the unit root hypothesis for Hong Kong, Indonesia, South Korea, Malaysia, the Philippines and Thailand. However, they do not incorporate a large amount of data in their post-crisis period, and it is worth investigating the sensitivity of the data to structural changes – the lack of post-crisis data may be causing incorrect results. It would be anticipated that the currencies did not contain a unit root in the pre-crisis period, as the majority were pegged or otherwise government controlled. The post-crisis results may differ as many currencies were floated or had their controls loosened subsequent to the crisis (see Table 4-2).

The authors also fail to list the dates of structural breaks determined by the Zivot and Andrews test. Assumptions can be made about the breaks from the quoted values of λ – those values around 0.95 appear to occur during the crisis or post-crisis period. From this assumption, it appears breaks were identified in the crisis period for Hong Kong, South Korea, Malaysia, the Philippines, and Singapore. Note that in their analysis, Taiwan and Indonesia did not appear to register breaks in the crisis period as both had very small values for λ, which is an unlikely scenario given that Indonesia floated its currency during this period. The Zivot and Andrews test will be used in this thesis to test for unit roots over time periods incorporating the 1997 East Asian crisis, when studies such as Granger, Huang and Yang have indicated that structural breaks have taken place in a number of East Asian currencies.

2.6.2 Cointegration

Baillie and Bollerslev (1989a) observe that not only are daily foreign exchange rates unit root processes, but also that daily spot and forward exchange rate series are cointegrated. The identification of long-run relationships in currency series is important, as the hedge ratio may otherwise be misspecified (Lien, 1996). Aggarwal and Mougoué (1996) observe that the existence of cointegration suggests opportunities for cross-hedging as a means of hedging foreign exchange risk in currencies where developed markets for currency forwards and futures do not exist, as it demonstrates an existing long-run relationship between the asset and the futures being used to cross-hedge it. Hence an important step in any study of cross-hedging is the identification of long-run cointegrating relationships between spot and futures.

Cointegration describes the relationship between two time series, y and z, and can be modelled by a simple OLS regression, such that:

$$y_t = \alpha + \beta z_t + \varepsilon_t \tag{34}$$

where $\varepsilon \sim (0, \sigma_\varepsilon^2)$. If the distribution of the error term ε_t doesn't change over time, then the model is stationary and describes two series that have a long-run cointegrating relationship. This is the standard OLS regression form, as is commonly used to analyse economic variables. However, as discussed previously, foreign exchange series are often characterised as non-stationary (Hsieh, 1988) and may be heteroskedastic (Hsieh, 1991) and/or autocorrelated (Liu and He, 1991). As a result, the OLS regression may incorrectly interpret a null hypothesis, resulting in the hypothesis being accepted or rejected too often for a given level of significance. Indeed, Hsieh (1991) states that heteroskedasticity should be adjusted for when using OLS regression over exchange rate changes.

When using an OLS regression to test for a cointegrating relationship, there are several important points that must be considered. One basic premise of the OLS regression is that the time series examined should contain a similar unit root profile (i.e. contain the same number of unit roots), and if this is not the case then a standard OLS regression should not be relied on to produce evidence of cointegration. Frankel and Wei (1994) conclude that East Asian currencies do not contain unit roots (and hence are not *I(1)* processes), and then go on to use a standard OLS regression to test for cointegration. The results from this study are therefore questionable, as they have failed to satisfy one of the essential criteria of cointegration testing.

Also an issue is the use of weekly or daily data, which introduces the possibility of heteroskedasticity due to the high frequency of observations (Hsieh, 1991). It can be anticipated that daily exchange rates will be influenced to some extent by lagged data (Baillie and Bollerslev, 1989b), hence there may also be some degree of autocorrelation. A further drawback of regression analysis that is highly relevant to this thesis is the fact that several East Asian currencies moved from managed exchange rate regimes to market driven regimes post-crisis. A regression analysis, based on the supposition that a currency basket is being adhered to, is obviously less conclusive an analysis tool in the post-crisis period. As most of the previous work has been done during periods of managed exchange rate regimes, this analysis was more appropriate but it may be criticised for its simplicity and lack of investigation into spurious regression results when applied to the post-crisis period.

Engle and Granger (1987) propose a basic methodology for cointegration testing. They show that a linear combination of *I(1)* series will generally be *I(1)* unless there exists some cointegrating relationship, which will result instead in an *I(0)* process, and therefore it is possible to test for cointegration between series by testing for the null hypothesis of no cointegration. Should the two series be of differing orders, *I(n)* and *I(m),* then it is possible to conclude that they are not cointegrated. Having established the presence of unit roots of the same order in two series, the equilibrium relationship can be estimated of the form

$$y_t = \beta_o + \beta_1 x_t + \varepsilon_t$$

(35)

where y_t is one economic time series and x_t the other, with errors ε_t. An OLS regression can be run from this equation, and the residuals examined to determine if they are *I(0)*. Engle and Granger show that the standard Dickey-Fuller critical values are not appropriate to test this, and instead use a set of critical values they generated for the purpose. This technique was further refined by Engle and Yoo (1987) for situations where the relationship is characterised by more than two variables. This form can be rewritten as a vector, such that

$$\begin{aligned} Y_t &= \beta_1 X_t + u_{1t} \\ X_t &= \beta_2 Y_t + u_{2t} \end{aligned}$$

(36)

where $u_{1t} = u_{1t-1} + \varepsilon_{1t}$,

$u_{2t} = \rho u_{2t-1} + \varepsilon_{2t}$,

and $E(\varepsilon_{1t}) = E(\varepsilon_{2t}) = 0, \mathrm{var}(\varepsilon_{1t}) = \sigma_{11}, \mathrm{var}(\varepsilon_{2t}) = \sigma_{22}, \mathrm{cov}(\varepsilon_{1t}, \varepsilon_{2t}) = \sigma_{12}$

The components of the vector X_t are said to be cointegrated *CI(d,b)* if all components of X_t are integrated of order *d*, and there exists a cointegrating vector β such that the linear combination $\beta_1 X_t$ is integrated of order (*d-b*) where $b > 0$. Y and X can therefore be said to be cointegrated *CI(1,1)*.

2.6.2.1 Johansen Test for Cointegration

The Johansen (1988, 1990) test for cointegration is based on the autoregressive error-correction model - if two series are cointegrated, then it follows that they have an error-correction representation. The basic vector error-correction equations are modelled under an assumption of cointegration, and tests are then carried out to determine if the model does in fact fit the data being tested. The vector auto-regression can be restated to give:

$$\Delta X_t = \alpha\beta' X_{t-1} + \Gamma \Delta X_{t-1} + \mu + \Phi D_t + \varepsilon_t \tag{37}$$

where X_t is the matrix of time series data,

α is the matrix containing the coefficients of adjustment *(n x r)*,

β is the matrix containing cointegrating vectors*(n x r)*,

Γ is the matrix of the short-run coefficients *(n x n)*,

μ is a growth rate,

and D_t is a matrix of seasonal dummy terms *(n x d)*.

The matrix $\Pi = \alpha\beta'$ can be used to determine the number of cointegrating vectors, with three possible outcomes. When the presence of a unit root in the data has been ascertained, this can be reduced to the one main scenario such that X_t is $I(1)$ and Π is the outer product of two *(k x r)* matrices each of rank *r*. The task, then, is to determine the cointegrating rank r, factorise $\Pi = \alpha\beta'$ and from this estimate the VAR. The hypotheses are developed such that

H_0 *: no cointegrating equations*

$H_1 : \Pi = \alpha\beta'$

The Johansen and Juselius (1990) cointegration test determines cointegrating rank using maximum likelihood estimation of the eigenvalues of Π. This generates a likelihood estimate for each hypothesis $H_0 \ldots H_{k-1}$. The resulting estimates are then compared to the Osterwald-Lenum (1992) critical values to determine if the hypothesis can be rejected, thus determining the number of cointegrating equations.

Early work on cointegration between currency series includes that by Baillie and Bollerslev (1989b), who found evidence of cointegration between 7 major currencies using PP tests on a composite OLS model. However, this method received some criticism with regard to the strength of the results, and other studies[20] criticised the conclusions. Subsequent studies (Zhou, 1998, Granger, Huang and Yang , 2000, Azali, Habibullah and Baharumshah , 2001) instead use the Johansen test for cointegration, and it has been incorporated in a variety of statistical packages and is now widely used in cointegration literature. However, poorly characterised high-frequency data may still generate incorrect conclusions if allowances are not made for the impact that structural breaks may have on the series. Baillie and Bollerslev (1994) observe that the impact of structural breaks will be minimised by using long-run data, and suggest that those relationships that show cointegration more strongly over the long run should be termed "fractionally integrated" processes. It is possible that long-run data may not be the most appropriate for use in some applications, and it may be important that the impact of structural breaks be fully recognised, and not "minimised" as suggested by Baillie and Bollerslev. In view of this, work was done in the late 1990s that sought to capture the structural breaks and allow data analysis that incorporated, rather than ignored or minimised, the impact of the breaks on the time series.

2.6.2.2 Gregory and Hansen Test for Cointegration

The Gregory and Hansen (1996) test for cointegration expands the test for cointegration to enable testing over periods incorporating structural breaks and includes the independent derivation of an appropriate breakpoint. The test is based on a regime

[20] see Sephton and Larsen (1991)

switching methodology, whereby a residual-based test for cointegration is used which allows for a regime shift in the intercept alone, or the entire coefficient vector. Like the Zivot and Andrews (1992) test for a unit root, the selection of breakpoints for the structural change is done empirically, hence again removing the possibility of arbitrary period selection. The Gregory and Hansen (GH) test may therefore be regarded as a multivariate extension of the univariate Zivot and Andrews test. The GH test is broken up into two stages. Again the level shift with trend model is used as per Granger, Huang and Yang (2000), such that

$$y_{1t} = \alpha + \beta t + \gamma DU_t(\lambda) + \theta_1 y_{2t} + \varepsilon_t \tag{38}$$

where	y_{1t}, y_{2t}	are *I(1)* time series,
	$DU_t(\lambda) = 1$	for $t > T\lambda$,
	$= 0$	otherwise, as per the ZA test,
and	$\lambda = Tb/T$	with Tb being the point of the structural break.

The residuals are then tested to determine if they are *I(0)* or *I(1)* processes using the standard ADF and PP unit root tests using a generated set of critical values. If the residuals are *I(0)* processes, this indicates the presence of cointegration between y_{1t} and y_{2t} and hence the null hypothesis of no cointegration can be rejected. The point of the structural break is determined from the value of λ that generates the smallest ADF and/or PP test statistic.

The Gregory and Hansen test has been adopted in recent research (Hamori and Matsubayashi, 2001, Felmingham and Zhang, 2001, Dharba, 2002). While most applications deal with economic series, some research has used exchange rate data. Granger, Huang and Yang (2000) use the Gregory and Hansen test to test for cointegration between East Asian exchange rates and stock market indices. While focussing solely on the exchange rates determined previously in the study to contain unit roots (Japan, Singapore and Taiwan), they find evidence of cointegration between the exchange rates and stock market indices for these countries[21]. Fernandez-Serrano and Sosvilla-Rivero (2001) also use the Gregory and Hansen test for cointegration to examine linkages between Asian stock markets during the period 1977 – 1999. They examine daily data from the stock market indices of Hong Kong, Japan, Singapore, South Korea and Taiwan, using the Japanese market as a basis from which to seek cointegrating relationships. While the Gregory and Hansen test finds support for regional stock market cointegration between Japan and Taiwan, with weaker support for Japan-Singapore and Japan-Korea over sub-periods, the Johansen test fails to reject the null of no cointegration. Indeed, in one instance the authors introduce a dummy variable to allow for structural change and are still unable to reject the null hypothesis using the Johansen test. They conclude that there is evidence of long-run relationships in the data, and that traditional tests of cointegration that fail to incorporate structural breaks may misspecify cointegrating relationships.

In light of this evidence, the Gregory and Hansen test will be used in this thesis to test for long-run relationships in East Asian currencies over periods incorporating the 1997 crisis.

2.6.2.3 Length of Study Period

Baillie and Bollerslev (1989a) recommend the use of high-frequency data when analysing the relationships between currencies. They note that "the degree and

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[21] Note that this study does not test for cointegrating relationships between any currency pairs.

persistence of time-dependent heteroskedasticity and the level of kurtosis are far more pronounced in daily than weekly exchange rate data"[22]. They also observe (Baillie and Bollerslev, 1994) that the impact of structural breaks will be minimised by using long-run data. As the study period for this thesis incorporates the crisis of 1997, structural breaks both natural and caused by government intervention in the nature of the currencies (such as the decision to float or fix various currencies during this period) means that the exchange rate series are likely to contain significant structural breaks. It is important, therefore, to consider this throughout the analysis process of this thesis as daily data will be used throughout.

Baillie and Bollerslev (1994) also note that since their 1989 study of cointegration in exchange rate series, work by other researchers has shown that the selection of study period will influence the significance of the outcome of cointegration tests. Researchers should therefore be careful about conclusions drawn as a result of cointegration testing - it is not possible to infer that currencies will always be cointegrated simply because evidence of cointegration is found for a specific time period. It is possible that conflicting results may be found if the selection of start and end dates are chosen differently. As such, it is important to avoid making sweeping generalisations based on period-specific results.

2.6.2.4 East Asian Currency Studies

There is a limited amount of research into East Asian currencies, and they typically focus on the Japanese yen and do not include the Australian dollar. In some cases these studies test for unit roots and cointegrating relationships, but their results are

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[22] Baillie and Bollerslev (1989a), p. 169

inconclusive at best, and changes in East Asian currency regimes naturally make the results period specific. Zhou (1998) examines the relationship between the currencies of ten Pacific Basin countries, specifically Australia, New Zealand, China, Thailand, Indonesia, Malaysia, Hong Kong, Korea, Singapore and Taiwan, and their linkages to the Japanese Yen and the US Dollar, using quarterly data from 1973 to 1993. Zhou finds that there is a significant relationship between the Yen and the Singapore Dollar, the Korean Won and the Taiwan Dollar. However, Zhou also finds no significant relationship between the Australian Dollar and the Yen. Zhou further finds that the currencies of Australia, New Zealand, Singapore, Korea and Taiwan are *I(1)* processes, while Malaysia and Thailand are *I(0)*. However, Baharumshah and Ariff (1997) studied purchasing power parity (PPP) in Thailand, Singapore, the Philippines, Malaysia and Indonesia and use both the ADF and PP statistics to show that these currencies are all *I(1)* processes.

Likewise Azali, Habibullah and Baharumshah (2001) examine East Asian and Japanese currencies search of support for PPP, in this case using panel analysis techniques. They find that the East Asian currencies of Indonesia, South Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand were *I(1)* processes over the study period. However, the last period for this study was the 4^{th} quarter of 1997, and therefore includes the 1997 crisis, although there is no adjustment made for structural breaks. It should also be noted that both Baharumshah and Ariff (1997) and Azali et al. (2001) use long-run (annual) data in their examinations, which may mitigate for the structural breaks as noted by Baillie and Bollerslev (1994). In a more recent study of emerging markets, Holmes (2002) uses quarterly data and draws similar conclusions.

Few studies have been made of intra-Asia currency cointegration prior to the 1997 currency crisis. One of these studies is Aggarwal and Mougoué (1996) who looked at relationships between the Japanese Yen and two groupings of Asian currencies, defined as the "Tigers" (Hong Kong, South Korea, Singapore and Taiwan) and the ASEANs (Malaysia, Philippines, Thailand and Singapore). At the time the paper was written, there was an interest in the increasing dominance of Japan over the Asian region, and the paper attempts to find empirical evidence of this in the relationships between the region's currencies. The period studied is 1983 to 1992, and so covers the period of Japan's ascendency as a global economic power. After confirming the presence of unit roots in the exchange rates using the Park and Sung (1994) test for unit roots in data with structural breaks, subsequent cointegration testing finds that for the second time period examined (1988 – 1992), the Japanese yen was found to be influential in both sets of currencies, and in fact was more influential than the U.S. dollar (the assumption being that the US dollar is the most highly related currency to those of East Asia).

They show also, through the implementation of cross-hedges, that the Japanese yen is a suitable currency with which to hedge these East Asian currencies. Tse and Ng (1997) study the currencies of Japan, Malaysia, Singapore, the Philippines, Thailand, Taiwan and South Korea, using daily data from September 1982 to June 1994, and find evidence of multilateral cointegrating relationships in a full system of these exchange rates, starting in the early 1990s. Reside and Gochoco-Bautista (1999) use average monthly rates to study the exchange rates of China, Japan, Malaysia, the Philippines, Thailand, Indonesia, Singapore and South Korea from July 1992 to December 1997 but find no evidence for bilateral cointegration between the Yen and any of the East Asian currencies using the Johansen (1988) test. They do find support for a multilateral cointegrating relationship between China, Thailand, the Philippines, Singapore, Indonesia and Japan.

2.7 Summary

This chapter has discussed the literature of hedging within the framework of the three theories of hedging: traditional hedging theory, the Working (1953) theory of speculation on the basis, and the portfolio model of hedging. A number of hedge ratio estimation techniques were discussed in section 2.1.1, including the three techniques used in this thesis: the Ederington minimum variance hedge ratio of equation (9), and the error correction model hedge ratio of equation (17), and the lower partial moment hedge ratio of equation (20). Additionally, a number of different hedge performance assessment techniques have been discussed in section 2.3, including the R^2 measure, the Sharpe ratio and the HBS measure, all of which will be used in this thesis to evaluate hedge performance.

An error correction model hedge may outperform other ratio estimation techniques if a long-run relationship exists between spot and futures. In order to ascertain the nature of this relationship, unit root and cointegration tests are used, and these are discussed in section 2.6. Of particular relevance to this thesis are tests used in the presence of structural breaks, such as those in several East Asian caused by regime changes during the 1997 crisis. Unit root and cointegration testing is carried out in Chapter 6, and the results validate the decision to use error correction model cross-hedges in Chapter 7.

This thesis builds upon work such as that of Eaker and Grant (1987) and Aggarwal and Demaskey (1997), and examines the effectiveness of currency cross-hedges implemented using different ratio estimation techniques. Chapter 7 examines the effectiveness of cross-hedges implemented using a full hedge, the Ederington minimum variance hedge ratio and the error correction model hedge ratio. Chapter 8 takes this a step further, examining the effectiveness of lower partial moment hedge ratios in cross-hedging, something that has not previously been documented in the literature. The results of this thesis are then discussed further in Chapter 9, and recommendations for future work are made.

3 Economic Background

3.1 The Asian Currency Crisis – A Brief Overview

A financial crisis can be defined as "a non-linear disruption to financial markets in which the asymmetric information problems of adverse selection and moral hazard become much worse" (Mishkin, 1999, p. 710). The Asian currency crisis of 1997 undoubtedly devastated the region, destroying regional economies and threatening to wind back the progress made over the previous 5-10 years. The emerging markets of Asia had been booming in the early part of the 1990's, with increasing foreign investment inflows as a result of the liberalisation of the finance sectors and the rapid economic growth being experienced. The crisis in Asia was generally unanticipated. Ratings agencies such as Moodys and Standard and Poor's failed to downgrade sovereign debt in the lead up to the crisis – indeed, in some instances the ratings were improving. When the crisis hit, it did so forcefully and with catastrophic results.

Since then, the economies have recovered and reorganised, and have been the subject of many post-mortem studies. Most researchers agree that the crisis was caused by the liberalisation of financial systems without the counterbalancing regulatory and supervisory regimes required to ensure proper market behaviour. As a result, bad loans became dominant feature of the banking systems in each country, while hordes of political cronies were made insolvent when expansive business ventures collapsed in debt. Mishkin (1999) proposes that the main determinant of financial crises is a deterioration in the balance sheet of financial sector institutions. Significant banking sector changes, making the availability of money far greater, resulted in excessive risk-taking with borrowed money. Mishkin attributes this risk-taking to a lack of experience within the banking sector, coupled with inadequate regulatory systems in political regimes riddled with corruption. Government guarantees on the banking system, or the assumptions of those guarantees, create a situation where moral hazard invariably results, with large loans being made to inappropriate borrowers. Further, an inflow of OECD capital as a result of a booming economy and high yields means that the money supply is further increased, encouraging more loans. Mishkin posits that the deterioration of bank balance sheets precipitated the financial crisis in Asia. This, coupled with a large current account deficit, can trigger speculative attacks on a currency that central banks are unable to defend. A rise in interest rates could trigger a collapse in the banking sector due to the quantity and quality of outstanding loans (the study notes that the share of non-performing loans to performing loans rose by 15-35% during the Asian currency crisis). These conditions may lead to a currency crisis and subsequent devaluation (Mishkin, 1999).

Mishkin notes that the ensuing currency devaluation causes financial crisis, emerging markets being particularly vulnerable because their short-term debt tends to be denominated in OECD currencies. Assets, denominated in the domestic currency, are reduced in value and hence debt will begin to far outweigh assets thus precipitating a decline in lending and investment and therefore in economic activity. Currency devaluation may also result in inflation, and hence interest rate increases that further pressure borrowers. This also puts pressure on the banking sector, whose balance sheets weaken and whose foreign denominated debt comes under pressure. Banking sector collapse will further precipitate economic collapse.

Radelet and Sachs (1998b), however, note that some authors and particularly the IMF were quick to take up this explanation of credit crisis, which ignores the fact that the Asian economies had been spectacularly successful up until the crisis. The crisis was almost wholly unforseen and, until the crisis hit, Asian economies had experienced large and enthusiastic inflows of foreign capital. The authors examine three crises in emerging nations, namely the Mexican crisis of 1994-95, the Argentine crisis of 1995 and the East Asian crisis of 1997. In each case, they find the crises are characterised by panic-driven creditors rapidly withdrawing funds, creating an "unnecessarily deep contraction"[23]. Their argument is one of undershooting, where the panic creates a downturn that is excessive relative to that indicated by the underlying fundamentals of the economy. The authors instead blame the initiated but, at the time, incomplete process of financial market reforms that the crisis economies had begun. In each of the three 1990s crises, partial reforms had resulted in economic systems that were particularly susceptible to capital flight. However, unlike the South American crises, the Asian crisis was noticeably absent of possible trigger factors such as overvalued exchange rates and legacies of high inflation. The authors also note that there appeared to be no reason why the risk of credit default should have been of concern in the Asian economies prior to the crisis. Instead they characterise the Asian crisis as a credit crisis of illiquidity, where borrowers are unable to repay debts due to their holding of illiquid assets, rather than an insolvency-based scenario. Indeed, if the panic had not taken hold, there would have been no reason why the borrowers should be required to repay loans so quickly. The panic, in effect, became a self-fulfilling prophecy when collective action was taken by creditors.

Like Mishkin, Radelet and Sachs note that the crisis was exacerbated by newly liberalised banking systems that lacked regulatory supervision. Both political involvement in Asia's "crony capitalism" system and the involvement of major corporations in the banking business in several Asian nations conspired against an arms-

[23] Radelet and Sachs (1998b), p. 2

length, effective regulator. Indonesian and Korean banks were regularly allowed to breach capital adequacy requirements, a situation that would be unthinkable in OECD countries. Lending increased significantly pre-crash, with banks borrowing offshore to finance this activity. This left the banks particularly prone to the whims of overseas creditors, as was evident when the crisis set in. When domestic companies started to default on loans, the banks were caught in a credit squeeze. As many other domestic investments were in illiquid assets, such as property, the crisis worsened as property prices plunged and other assets devalued.

Bustelo (2000) characterises the Asian currency crisis as one precipitated by private over-investment. Certainly large capital inflows from foreign financing sources were a feature of the Asian economies pre-crisis and, as noted by Radelet and Sachs, the crisis was precipitated by large outflows of investment funds creating a credit squeeze. The Asian economies were characterized by large amounts of short-term foreign debt, and Bustelo notes that this area is lacking in consideration in some prior work on crisis indicators. Further, Bustelo points out that all three of the 1990s currency crises were in economies with significant government control over exchange rates and were in countries with large interest rate differentials. The business of borrowing overseas at lower interest rates, only to lend domestically at higher ones, was standard practice in Asian banks at the time leading up to the crisis. This was accompanied by a significant increase in domestic lending activity, in an environment of low regulatory supervision and low capital adequacy requirements. This resulted in an increase in domestic investments in non-liquid assets such as property, and over-investment by private firms that resulted in a decline in capital efficiency.

3.2 Indicators of a Crisis

A number of researchers have attempted to identify common characteristics of a financial crisis, in an attempt to allow identification of possible future crisis situations. The work of building models to predict a crisis was particularly prevalent in the latter part of the 1990s, after the crises in Argentina, Mexico and Asia. A belief that early identification could head off a crisis was fundamental to this work.

Berg and Pattillo (1999) analyse the popular KLR model of Kaminsky, Lizondon and Reinhart (1998) and propose modifications based on its handling of the Asian currency crisis. The original KLR model, which was based on data from crises in the period 1970 – 1995, fails to predict the East Asian crisis, casting its usefulness into doubt. The model uses fifteen indicator variables to predict a crisis, with each indicator triggering a warning signal when it moves beyond a given threshold. It then undergoes some further transformation to give a result that predicts the probability of crisis in the following 24 months. These indicators were based on a variety of economic indicators such as real exchange rate, exports, international reserves, real interest rate, imports, industrial production and terms of trade, as well as a financial indicator, namely the stock price index. The authors found that "the predictions [generated were] better than guesses"[24], however it is difficult to assess the success of a guess when full information is available. The authors then offer a probit model, using the same variables, that slightly outperforms the KLR model and better predicts the East Asian crisis. This shows that a variety of financial and economic factors can be identified that, when combined, may indicate the potential for the type of severe economic instability that can result in crisis.

[24] Berg and Pattillo (1999), p. 568

In attempting to build a model for predicting crises, Burkart and Coudert (2002) use a variety of factors as indicators including a regional relationship indicator, based on regional contagion theories such as that proposed by Glick and Rose (1999), a currency overvaluation weighting, a dummy variable for capital controls and an indicator for rapid domestic credit growth. They conclude that these are some of the most important factors when defining a crisis, and are able to successfully predict 4 out of 5 crises studied. Models such as this one work moderately well in regional predictions. However, as noted previously, the East Asian crisis economies were disparate in their nature. While some experienced rapid currency appreciation prior to the crisis, others (such as Indonesia) did not. While some experienced significant changes in capital controls, others (such as Singapore) did not. This led to inconsistency in the results of Burkart and Coudert, who were able to identify a oncoming crisis in Thailand, Malaysia and the Philippines, but were unable to predict the crisis in Indonesia. More fundamental was the lack of anticipation of research prior to the crisis, and the unequivocal support for the success and growth of these economies by ratings agencies and the IMF[25]. Despite work done in the period immediately prior to the currency crisis, prompted by the crises in Mexico and Argentina, there was little international concern about the region in the period leading up to the crisis.

Burkart and Coudert (2002) also observe that there are concerns that the early prediction of a crisis may lead to a self-fulfilling prophesy as investors react in the anticipation of future trouble. As noted previously, a feature of most crises is a compounding flight to safety of investors that precipitates collapse, even when, as with Asia, the fundamentals appear to be relatively sound. As a result, careful objective measurement of a variety of indicators is necessary before any prediction of a crisis can take place. However, noting

[25] Bustelo (2000) notes that the IMF "even praised the soundness of Thailand's and South Korea's macroeconomic policies" in the *IMF Annual Report 1997* (footnote, p. 237)

the variables that make up a robust crisis model also sheds light on the factors that are likely to create trouble, and where the trouble may occur. Bustelo (2000) proposes that research should focus not on predictors of financial crisis, but on indicators of future trouble. Observing that each crisis has its own set of individual differences, Bustelo argues that the focus of future research should be on early-warning indicators rather than crisis predictors.

3.2.1 Japan and Currency Devaluation

An interesting perspective on the East Asian currency devaluation is given by Kwan (1998). Kwan argues that the East Asian currencies were strongly linked to the US dollar in the early part of the 1990's. As the value of the Japanese yen (relative to the US dollar) plummeted in the mid-1990s, the competitiveness of East Asian exports to Japan, priced in currencies pegged to the dollar, likewise declined. This resulted in significantly reduced export earnings resulting in the deterioration of current account balances. Kwan cites Thailand as an example: the baht appreciated around 35% against the yen, and export growth dropped from over 20% in 1995 to almost nothing in 1996. This generated a current account deficit of 7.9% of GDP[26].

Kwan posits further that changes in the yen-dollar rate are the major factor determining economic growth in the East Asian region. He argues that rather than creating economic stability, pegging currencies to the US dollar has created a system in East Asia that is highly unstable and subject to shocks. Kwan blames the peg system for the volatile sequence of boom and crisis seen in the Asian region throughout the last 20 years. Kwan argues for a yen bloc in East Asia, and for currencies to be floated or pegged to the yen in preference to the US dollar. He argues that had countries such as Thailand

[26] Kwan (1998), p. 285

assigned a higher weighting to the yen in their currency baskets pre-crisis, the economic consequences would have been greatly reduced as the East Asian currencies would have been allowed to devalue in step with the yen. This would have moderated the decrease in exports and resulted in a far less drastic outcome. Radelet and Sachs (1998b) concur with Kwan's assessment of the devaluation of the yen having an impact on the Asian economies, although they state that the devaluation of the yen had only "a modest direct impact"[27].

The overvaluation of the East Asian currencies is significant in Kwan's argument as well as other work on the nature of financial crisis. However, Chinn (2000) examines the possible overvaluation of the East Asian currencies and emphasises the fact that the subsequent devaluation of the currencies once government control was removed does not necessarily infer that the currencies were overvalued before the crisis. Based on a variety of tests, Chinn finds that while there is evidence that the currencies of Hong Kong, the Philippines, Malaysia and Thailand were overvalued, the reverse is true for South Korea, Taiwan and Singapore. Further, the author finds mixed evidence for Indonesia. The author notes that while the currencies of the Philippines, Malaysia and Thailand suffered a severe decline in value, the Hong Kong dollar did not. Likewise while Taiwan and Singapore suffered relatively less than other countries, the South Korean won declined significantly. Hence no relationship is obvious between pre- and post-crisis currency values. Chinn concludes that despite the subsequent devaluations, not all East Asian currencies were overvalued before the crisis. Chinn also comments that the degree to which currencies were overvalued was small, and hence any prior currency overvaluation was not a defining condition that led to a currency crisis.

[27] Radelet and Sachs (1998b), p. 3

As discussed previously, increased investment in the property sector made things difficult when sales were required. The currency crisis was coupled in many countries with a sharp decline in real estate prices. However authors such as Radelet and Sachs (1998b) note that there was no discernable "bubble" in property prices in the years leading up to the crisis. A property price bubble does not appear to precede the currency crisis, and lending for property could not be said to have been particularly risky. However the devaluation during the crisis did not help borrowers repay foreign denominated debt, as domestic price falls coupled with a devalued currency resulted in significant losses against property purchase prices. It should also be noted that some countries, like Indonesia, saw no decline in real estate prices until the following year (1998).

3.3 The Impact on Trade

After the rapid realignment (or devaluation) of East Asian currencies which took place when their controls were loosened, it took some time for exports to recover to their pre-crisis levels. Only a modest increase in export volume was noticeable in the immediate realignment period, the period including and immediately subsequent to structural change in the currencies. There are several reasons for this to have been the case. Basic economics dictates price elasticity of demand, and it is possible that the volume of exports was inelastic in the short term. A lack of growth in the countries importing Asian goods would mean that price falls would not necessarily result in an increase in demand. Another hypothesis is that corporate failures in the East Asian countries resulted in an inability to increase export production. However, Duttagupta and Spilimbergo (2000) find that the most likely cause of a failure to increase export volumes was the "competitive depreciation" that occurred as exchange rates fell relatively equally in all regional economies. This meant that no one country had a competitive advantage over any other, and so there was no marked increase in export volume in any one country. They noted that this was an important conclusion as normally East Asian export volume is extremely price-sensitive. They conclude that this competitive depreciation exacerbated the crisis, and prolonged it by keeping all competing economies depressed as none were able to gain a competitive advantage from currency depreciation.

Once the crisis started, primarily in Thailand, it spread rapidly throughout the region. Later studies by Glick and Rose (1999) indicate that currency crises are contagious along lines of international trade linkages. Countries prefer to trade with near-neighbour countries, so the spread of contagion through trading lines tends to result in geographically-related countries experiencing crisis. The research is relevant, as it shows that speculative "raids" on currencies occur along international trading lines. The authors show that once a country has been subject to a crisis, closely related trading partners and competitors were more likely to experience a similar crisis than unrelated countries. Edwards and Susmel (2001) further show that the contagion spreads rapidly and is characterised by short periods of extreme volatility, which also result in heightened levels of correlation between the affected countries stock markets.

Trade is also a reason given by Radelet and Sachs (1998b) as an important factor in the Asian currency crisis. The signing of the NAFTA treaty resulted in a significant increase in trade between the US and Mexico, whose manufactured products compete directly with those of East Asia. Likewise China's share of trade was steadily increasing, resulting in further pressure on East Asian exports. These factors would add to the effect noted by Duttagupta and Spilimbergo which resulted in the lag between currency devaluation and a surge in export volume. They note, however, that in general, the East Asian economies were not losing export market share to either Mexico or China.

Throughout the crisis, newspapers in Australia speculated that Australia would suffer a similar downturn due to its closeness to Asia as well as its dependence on trade with Asia. Great consternation was felt and many leading commentators predicted that the crisis would have a dire effect on the Australian economy. In the event, Australia came through the crisis with few problems and with trading levels almost unaffected by the problems in Asia.

3.3.1 Trade with Australia

There was a sound economic basis for concern about the possible ramifications of the currency crisis on the Australian economy. The last decade of the 20th century saw a significant increase in Australian trade with East Asia, both in exports to and imports from the East Asian region. Total trade flows between Australia and East Asia grew from AU$34.5 billion in 1989-90 to AU$82.4 billion in 2001-02, and exports to the ASEAN nations, China, Japan, Hong Kong, South Korea and Taiwan now comprise 53% of Australia's total merchandise trade exports[28]. While Australian exports suffered noticeably in the immediate aftermath of the Asian currency crisis (see Table 3-1), imports grew steadily throughout the decade (see Table 3-2). Australia is playing an increasingly important role in East Asia, particularly with regard to regional assistance programs. At any time, Australia is providing a variety of practical assistance programs to Asian countries including farming assistance, manufacturing and tourism initiatives and infrastructure projects, as well as general relief work focussing on areas in crisis. The involvement of Australia in Asia continues to grow steadily, in much the same way

[28] International Merchandise Trade, Australian Bureau of Statistics, released January 2003

as the trade flows have. The currency crisis had a small but significant impact on Australian trade, with exports decreasing by 5% in the two years subsequent to the crisis before recovering again at the end of the decade. The value of imports, however, increased throughout the period. Superficially, this may seem to indicate that the economies of Australia and East Asia are not so closely related and certainly the Australian economy was relatively unaffected by the 1997 crisis. Further analysis on the currencies using cointegration techniques will shed more light on the nature of relationships in the region.

3.4 Emerging Markets, International Portfolio Diversification and Hedging Strategies

Glen and Jorion (1993) demonstrated that an international portfolio, hedged against currency risk, offers a better risk-return profile than an unhedged portfolio. While this study examines developed economies, in the risky world of emerging markets large returns are to be had by those who dare to invest. However studies such as Bekaert and Harvey (1997) observe that equities in emerging markets have significantly different characteristics to those in developed capital markets. They are marked by higher volatility, have less correlation with OECD markets, and their returns may be more predictable. The volatile nature of emerging markets makes sound hedging strategy vital if investors do not wish to gamble on being in the right place at the right time. Any longer-term exposure to emerging markets is likely to incorporate periods of extreme volatility, and during those periods investors stand to lose large amounts of capital.

Table 3-1: Australian Exports (AUD $million) 1989 – 2002

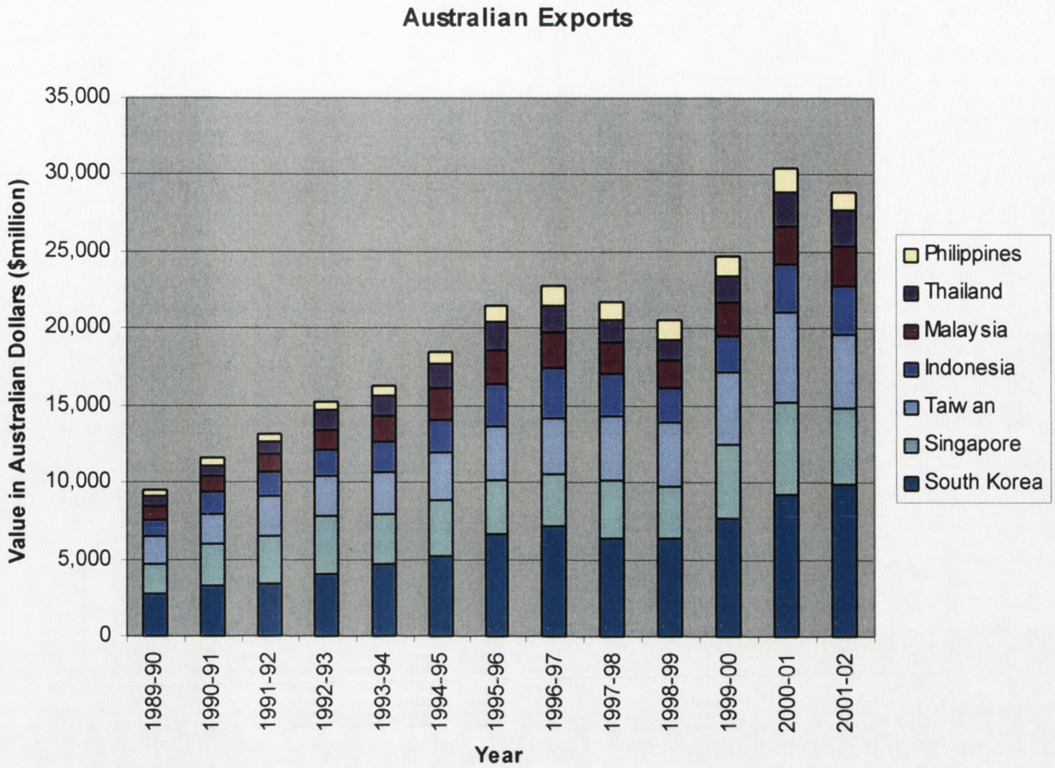
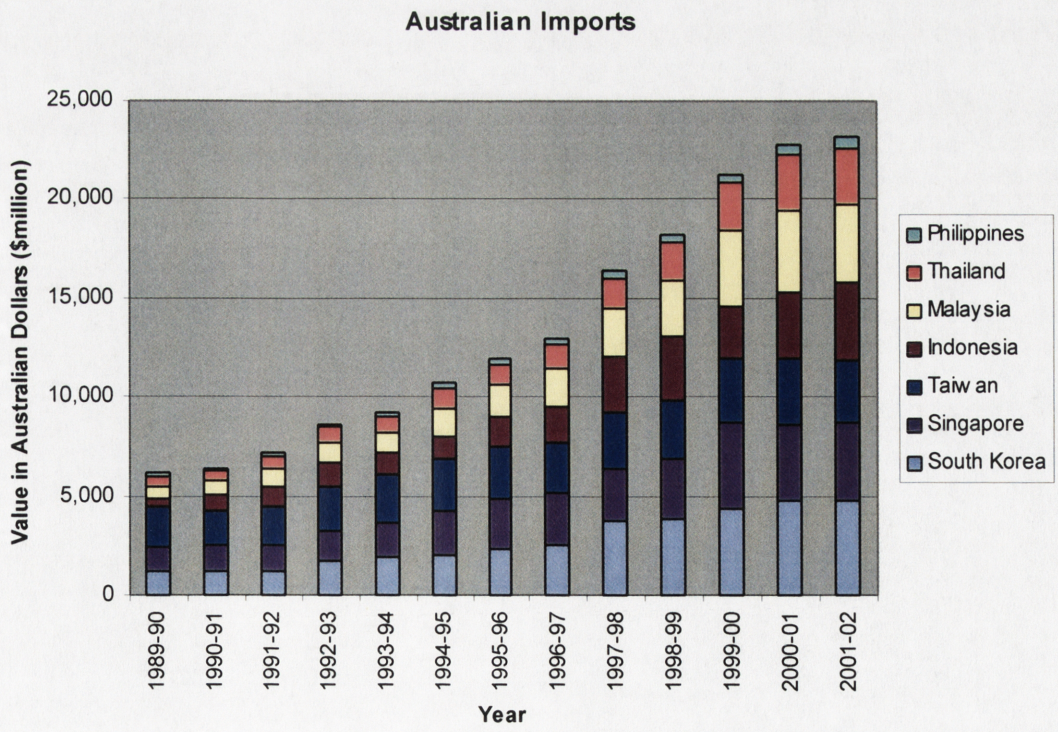


Table 3-2: Australian Imports (AUD $million) 1989 – 2002



Source : International Merchandise Trade, Australian Bureau of Statistics (5422.0)

An effective hedging strategy may help to minimise losses incurred during such periods of instability. Bekaert and Harvey (1997) also note that as emerging markets liberalise, the level of volatility decreases. Any hedging strategy used in emerging markets must therefore be flexible and be able to adjust rapidly to changing world conditions. This is particularly relevant in countries, such as those in East Asia, that are moving towards ever greater participation in world markets and the global economy. Further, Edwards and Susmel (2001) find that periods of high volatility are usually short-lived, typically lasting from 2 to 12 weeks per episode. These periods of volatility also tend to transmit between regionally co-located countries, emphasising the need for a hedging strategy that is both flexible and reactive.

Emerging markets are marked by periods of financial crisis as they move towards liberalisation, a risk often exacerbated by political interference and populist policies during the difficult process of adjustment to world trade. Pownall and Koedijk (1999) find that most risk management methodologies fail to accommodate the additional downside risk inherent in periods of financial crisis and as such are sub-optimal in emerging markets. Crises are marked by significant deviations from normality in returns, specifically large negative deviations. When analysts use the estimated variance of an asset as a measure of risk, the true risk may be significantly underestimated resulting in inadequate provisions in a risk management strategy. Pownall and Koedijk propose that when assessing risk in emerging markets, additional downside risk should be factored into all asset pricing models. Again, this makes a sound hedging strategy all the more important when dealing in emerging markets. Without a strategy that can accommodate the additional downside risk inherent in financial crises, investors in emerging markets may find themselves with losses that outweigh previous gains.

4 Data

4.1 Currency Data

Daily currency data was obtained from DataStream for the Indonesian rupiah, the Thai baht, the Singapore dollar, the Philippines peso, the Taiwanese dollar, the South Korean won, the Malaysian ringgit, the German mark, the Australian dollar, the New Zealand dollar, the Swiss franc and the Japanese yen for the period 01/01/1992 to 01/01/2002. Time series data for these currencies is taken from UK closing prices (5pm GMT) and as such is consistent across all currencies used in this thesis. In some of the analysis that follows, the study period has been split into two sub-periods to allow the generation of pre- and post-crisis statistics. Several sections use these sub-periods for analysis, primarily those comparing tests suitable for use during periods of structural change with those that are not adapted for structural change. In Chapter 5, the pre-crisis sub-period runs from 01/01/1992 to 1/07/1997, while the post-crisis sub-period runs from 02/07/1997 to 01/01/2002. In Chapter 6, the sub-periods differ, as they are selected so as to eliminate the period of the structural breaks observed during late 1997. This enables the effectiveness of unit root and cointegration tests to be examined without the confounding effects of structural breaks, and will be discussed in more detail in Chapter 6.

4.2 Currency Statistics

Studies such as Hsieh (1988) have examined the statistical properties of daily foreign exchange rates of major currencies (including the Japanese yen and the Deutschmark). Hsieh noted several common factors including leptokurtosis (fat tails).

Table 4-1 contains descriptive statistics for the exchange rates used throughout this thesis. The currencies of Australia and Germany exhibit the typical leptokurtic distributions of floating currencies, with kurtosis values near or slightly higher than 3. Japan has a more pronounced leptokurtic distribution, but, for each currency, there is little change in kurtosis between the pre- and post-crisis periods. In each case, the measure of skewness is marginally negative.

Rana (1981) comments that higher kurtosis values are found during pegged regimes compared to floating regimes, using Asian currency data from 1967 – 1977 to demonstrate this effect. This result is corroborated here, where some Asian currencies show extreme leptokurtic distributions, reflecting their more controlled exchange rate regimes. The leptokurtic distributions are extremely pronounced in the pre-crisis period for Indonesia, the Philippines, South Korea and Thailand, when most of the exchange rates had some form of government intervention. In the case of Thailand (which had a fixed peg regime) and to a lesser extent Indonesia and South Korea (managed regimes), decreases in the leptokurtosis are evident in the post-crisis period, reflecting the easing of government control over exchange rates. Malaysia, as noted previously, moved to a fixed exchange rate regime post-1997 and this increase in government control over the exchange rate is evident in the significant increase in kurtosis. Singapore remained unchanged between the periods, which reflects its unchanged exchange rate policy, while there was also an increase in kurtosis for Taiwan, perhaps indicative of government intervention. Australia, Germany and Japan all had small changes in kurtosis between the pre- and post-crisis periods, but nothing of a magnitude that would indicate intervention. With the exception of Taiwan, the skewness of each currency decreased after the crisis period.

Table 4-1: Currency Statistics[29]

	IND	MLY	PHP	SNG	SKOR	TWN	THAI	AUD	DMK	JPY
Mean	0.0637	0.0128	0.0261	0.0050	0.0213	0.0121	0.0217	0.0151	0.0142	0.0019
Maximum	31.5778	11.8716	8.7865	3.3961	13.6104	3.3931	17.0751	3.4808	3.4650	4.1339
Minimum	-23.5743	-11.4562	-11.0961	-3.9690	-20.1655	-4.9080	-6.2039	-5.1682	-2.9382	-7.6773
Standard Deviation	2.2186	0.7116	0.7713	0.3901	1.0069	0.4348	0.7721	0.6289	0.6676	0.7482
Skewness	2.3702	0.2098	0.6214	-0.6846	-1.3454	-0.0790	3.7568	-0.2811	-0.0205	-0.9329
Skewness (pre-crisis)	2.7196	0.9656	0.5004	-0.5369	1.1913	-0.8318	0.7120	0.2528	0.1633	-0.7227
Skewness (post-crisis)	1.5400	0.0787	0.4729	-0.6590	-1.0053	0.9120	-0.4945	-0.4670	-0.2648	-1.0905
Kurtosis	66.6524	88.0127	46.2665	19.8516	108.9164	25.6264	108.7371	7.3989	4.7968	11.9751
Kurtosis (pre-crisis)	34.5345	20.1639	54.2267	13.3152	77.3484	21.8770	132.7744	4.5853	5.4690	10.7870
Kurtosis (post-crisis)	29.9976	44.8695	31.0804	13.3913	53.7239	30.4880	13.3325	6.5804	3.8612	12.3049

Notes: Pre-crisis period is 1/01/1992 – 01/07/1997, post-crisis period is 02/07/1997 – 01/01/2002.

[29] Results are for the return series $R_t = \ln(C_t/C_{t-1}) * 100$, where C = currency.

4.3 Futures Data

Daily futures contract data was obtained from the Chicago Mercantile Exchange (CME) for the period 1/1/1990 to 31/1/2001. Contract details are as follows:

AUD: One futures contract represents $100,000 AUD. Quarterly listed six-month contracts maturing in March, June, September and December. One point = $0.0001 USD per AUD = $10 US per contract. These contracts are traded both on the trading floor, and electronically through the GLOBEX2 electronic exchange. This contract commenced trading in 1987. The AUD futures contract expires mid-month.

DMK: One futures contract represents 125,000 DMK. Quarterly listed three month contracts maturing in March, June, September and December. One point = $0.0001 USD per DMK = $12.50 US per contract. These contracts are electronically traded, but are not floor traded. This contract commenced trading in 1982 and will be used as the European currency for the period of the study. The DMK futures contract expires mid-month.

JPY: One futures contract represents 12,500,000 JPY. Quarterly listed six month contracts maturing in March, June, September and December. One point = $0.000001 USD per JPY = $12.50 US per contract. These contracts are traded both on the trading floor, and electronically through the GLOBEX2 electronic exchange. This contract commenced trading in 1982.

4.4 IMF Exchange Rate Classifications

The IMF classification for the exchange rate regimes of each country studied are given in Table 4-2. The nature of the exchange rate regimes for a number of the East Asian countries changed over the study period. Several East Asian currencies moved from managed to independent exchange rate regimes during the crisis period, the notable exception being Malaysia which moved to a fixed peg in 1998. The Philippines and Taiwan had moved to an independent regime in the 1980s, and so had floating currencies for the entire period of study. Singapore also remained relatively unchanged during the study period, having a managed float regime throughout.

Taiwan is not recognised by the IMF, and as such has no official IMF exchange rate classification. However, the Taiwanese government has instigated what would be regarded as an independent float regime by the IMF should they recognise the territory.

It is important to note that while the IMF has classified several regimes as independent floats, some research (including that originating with the IMF) argues that this is not the case. McKinnon (2000) uses the regression method of equation (38) to argue that Indonesia, South Korea, the Philippines and Thailand have returned to a managed regime, and are actually engaging in high-frequency pegging activity. However, Baig (2001) examines these currencies using a range of factors including exchange rate volatility, interest rate volatility and exchange rate flexibility, and finds support for looser post-crisis regimes. Baig argues that while these currencies still seem be weighted significantly toward the US dollar, they have not reverted to their pre-crisis levels of stability.

Table 4-2: Currency Regimes

Country	Regime Pre-Crisis	Regime Post-Crisis
INDONESIA	Managed Float	Independent Float (August 1997)
MALAYSIA	Managed Float	Fixed Peg (September 1998)
PHILIPPINES	Independent Float	Independent Float
SINGAPORE	Managed Float	Managed Float
S. KOREA	Managed Float	Independent Float (December 1997)
TAIWAN[1]	Independent Float	Independent Float
THAILAND	Fixed Peg	Independent Float (July 1997)
AUSTRALIA	Independent Float	Independent Float
GERMANY	Independent Float	Independent Float
JAPAN	Independent Float	Independent Float

Independent Float: the exchange rate is market determined.

Managed Float: the monetary authority influences the movements of the exchange rate thought active intervention in the foreign exchange market without specifying a regular pre-announced path for the exchange rate.

Fixed Peg: the country pegs its currency at a fixed rate to a major currency or basket of currencies, where a weighted composite is formed from the currencies of major trading or financial partners and currency weights reflect the geographical distribution of trade, services or capital flows.

Definitions from IMF Annual Report 2002

[1] Taiwan is not recognised by the IMF

Baig concludes that it does not appear that the majority of East Asian currencies have reverted to their pre-crisis pegging behaviour, and that while currencies may not be as freely floating as less controlled currencies, they exhibit less managed behaviour than prior to the crisis. The regime changes of the crisis period do not appear to have been unwound, and they continue throughout the post-crisis period of this study.

4.5 Summary

The currencies of East Asia studied here, namely those of Indonesia, Malaysia, Singapore, Thailand, the Philippines, South Korea and Taiwan, were all affected to varying degrees by the East Asia crisis of 1997. Indonesia, Thailand and South Korea experienced significant regime changes, moving from more controlled to floating regimes, while Malaysia reverted to a fixed peg in response to the crisis. In each case, a period of exchange rate volatility surrounded the crisis, and it is likely that the intra-regional currency relationships have changed significantly in the post-crisis period. Regime changes are likely to have resulted in structural breaks in the currency series, and this will be investigated further in Chapter 6, while Chapter 5 will investigate the relationships between the currencies in more detail.

5 Yen Bloc or Koala Bloc? Asian Currency Relationships and the Effects of the East Asian Crisis

This chapter examines the concept of the yen bloc in detail and revisits the techniques used by prior studies to see if the same conclusions would be drawn had the studies been performed in post-crisis East Asia. In many cases, previous studies neglected to choose a regional currency for contrast, relying instead on a European proxy (usually the German mark) to act as a control. Conclusions were often drawn based on questionable evidence. When these studies are replicated in the post-crisis period with the Australian dollar, they draw out two items of interest. Firstly, the strength of the Asia/Australia and Asia/Japan linkages in post-crisis East Asia are often similar, and so there may be evidence for a "koala bloc" as surely as there is evidence for a yen bloc. And given this, the question must be asked – was the evidence of a yen bloc as strong as previously suggested? Certainly the evidence presented here and in Chapter 6 shows that the yen bloc has not increased significantly in post-crisis East Asia, while the "koala bloc" is noticeably a feature of the post-crisis period. This chapter examines the question of "koala bloc" vs. yen bloc in more detail.

5.1 Introduction

During the late 1980s and early 1990s, there was a global fascination with the establishment of Japan as a major player in the world economy. Everything from Japanese management techniques to Japanese fashion design came under intense scrutiny and it is only natural that economists and finance academics likewise focussed on Japan, particularly the increasing influence of Japan in the Asian region and beyond. As Japan became a dominant economy it expanded its trading and investment network.

East Asian countries, as near neighbour economies, were obvious recipients of Japanese investment, both direct and indirect. Financial and economic research was generally geared toward demonstrating that Japan, as the dominant economy in East Asia, was forming a trade and currency block. The existence of a Japanese currency bloc in Asia, referred to as the yen bloc, can be demonstrated by increased levels of cointegration between the yen and other Asian currencies. However, these studies focussed almost solely on Japan, and few sought to contextualise the dominance of Japan by contrasting the results with other major economies in the region. As a result, the evidence presented may not be as compelling as the literature asserts. The question must be asked: are there grounds to confirm the existence of a bloc in one currency when there is similar evidence for a bloc in another currency? The results here demonstrate that significant relationships exist between the Australian dollar and several East Asian currencies in the post-crisis period. Is the "koala bloc" is a neglected feature of the East Asian economies? Or has perhaps the case for the yen bloc been overstated?

Both Australia and Japan play a significant role in the economies of East Asia, as discussed previously in section 3.3. It is interesting, therefore, to contrast the levels of cointegration between the East Asian currencies and these two developed near-neighbour economies, and to examine if there were any readjustments in these relationships in the changed currency regimes of post-1997-crisis East Asia. This thesis finds as much evidence for the existence of a "koala bloc" as for a yen bloc in the post-crisis period, indicating an increasing Australian economic presence in Asia along with a stagnating Japanese one. While many studies of the early 1990s noted a significant and growing Japanese economic presence, this growth seems to have stabilised since the 1997 East Asian currency crisis, while the Australian currency has gained influence in several post-crisis East Asian currencies. It seems there are now two important regional players, Australia and Japan, both of which should be considered in future studies of the East Asian economies.

5.2 Literature Review

During the early 1990's, a body of literature evolved that proposed and investigated the development of economic and/or currency blocs. Frankel (1993) described an economic bloc as "a group of countries that are concentrating their trade and financial relationships with one another, in preference to the rest of the world ... as an outcome of government policy"[30]. Three main blocs were perceived to be forming: that of Europe (which has subsequently formalised into the European Union), the Americas (centred around the U.S. and the North American Free Trade Agreement) and Asia (centred on Japan and alliances such as ASEAN). Frankel comments further that "Japan is forming an economic bloc ... by means of such instruments as flows of aid, foreign direct investment, and other forms of finance, to influence its neighbours' trade toward itself"[31]. The arguments for and against this have been made in many papers in the economic, sociological and financial disciplines.

Evidence of economic blocs may be found quantitatively in the relationships between currencies in the bloc, and the studies of Frankel and Wei (1994), Kwan (1996), Aggarwal and Mougouè (1996), Zhou (1998), and Gan (2000) focus specifically on assessing the inter-currency relationships, looking for evidence of a yen bloc. These studies form the basis of this paper, and their methodologies are replicated here over the

[30] Frankel (1993), p.53
[31] Frankel (1993) p.54

post-1997 East Asian crisis period to see if their findings still hold in light of the significant regime changes that took place during the crisis.

Prior to the 1990s, there was little evidence that the yen was playing a significant role in the currency management strategies of East Asia. Rather, the US dollar was the dominant currency, and studies such as Frankel and Wei (1994), who examine a range of currencies including the Australian dollar and the yen, show that the US dollar was the dominant influence on East Asian exchange rates during the study period. Any evidence for linkages in favour of the yen are attributed primarily to the overvaluation of the US dollar during the 1980s. While the study finished in 1992, and while Frankel and Wei conclude that the US dollar remained the dominant currency influencing East Asia, they note that there is evidence of yen links with the currencies of Singapore, Malaysia and Thailand during the final two years of the study.

Kwan (1996) seeks to determine the weightings of the German mark and Japanese yen in the currency baskets of the East Asian economies, plus Hong Kong and China, during a sub-period of 1995. Kwan argues that international currency market movements in the spring of 1995 represent a change in sentiment in East Asia, with some countries moving away from placing the US dollar at the centre of their currency management strategies and increasing the share of the yen in reserves. Kwan notes that the weightings for the yen derived for the currency baskets during this period are substantially greater than those found by Frankel and Wei (1994), indicating an increased level of regional integration.

Aggarwal and Mougouè (1996) examine relationships between the Japanese yen and two groupings of Asian currencies, defined as the "Tigers" (Hong Kong, South Korea, Singapore and Taiwan) and the ASEANs (Malaysia, Philippines, Thailand and Singapore). At the time the paper was written, there was an interest in the increasing dominance of Japan over the Asian region, and the paper seeks empirical evidence of this in the time-series relationship between the region's currencies. The period investigated (1983 to 1992) is that of Japan's ascendency as a global economic power. Cointegration testing finds that the yen was influential in both sets of currencies during the latter period of the study (1988 – 1992), and, in contrast to the findings of Frankel and Wei (1994), the yen was more influential than the U.S. dollar. Zhou (1998), studying a similar period, also finds evidence for a significant relationship between the yen and the Singapore dollar, the Korean won and the Taiwan dollar. Gan (2000) examines the elasticity of Asian currencies with respect to changes in the yen-dollar rate in the immediate pre- and post-crisis periods for evidence of a change in the weighting of currency pegs in the East Asian economies. Gan finds evidence that the managed currencies have been re-weighted, and that subsequent to the crisis all countries (excluding Malaysia after the ringgit was fixed) had increased their weighting of the yen.

Overall, the results of these studies are best summarised by Zhou (1998), who concludes that there is "a notable influence of the Japanese yen in the region"[32]. It is relevant, therefore, to ask if this has changed in any way since the 1997 Asian crisis, and to ask whether the yen bloc was the only major regional influence other than the US dollar.

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[32] Zhou (1998), p. 82

5.3 Results

This chapter replicates the techniques used in the research discussed in section 5.2, recreating them with the yen and introducing the Australian dollar as an alternative, regionally related currency. In most prior studies the Australian dollar was not included, and few include the post-1997 crisis period. As is evident from the exchange rate regime changes seen during this period (Table 4-2), the situation in Asia has changed notably and an update of these analyses is warranted.

Regression analysis is carried out as specified in the prior literature for the pre-crisis period (1 January 1992 – 1 July 1997) and the post-crisis period (2 July 1997 – 1 January 2002), the break being positioned as per Gan (2000). The techniques used in these prior studies can be grouped into two categories: those using standard OLS regression analysis, and those using Johansen cointegration analysis. Previous studies often assume the existence of a unit root in the currency series although there is not significant evidence to support this, particularly over the time period examined by Frankel and Wei (1994)[33]. The Frankel and Wei study concludes that the East Asian currencies did not contain a unit root during the study period and hence were not *I(1)* processes, while Aggarwal and Mougouè (1996) find evidence to support the unit root hypothesis using the Park and Sung (1994) procedure that accommodates structural breaks. A more comprehensive characterisation of the data has been undertaken in Chapter 6, where the stationarity of exchange rates is investigated in more detail, but is outside of the scope of this chapter which intends to focus purely on simpler analysis methods reported in the literature.

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[33] January 1979 to May 1992

The OLS regression analysis undertaken is similar in most cases to the form used by Frankel and Wei (1994) to determine the role played by various OECD currencies in nine East Asian currencies using weekly data. The Frankel and Wei regression is modelled as:

$$\Delta C_t = \alpha + \beta_1 \Delta U_t + \beta_2 \Delta Y_t + \beta_3 \Delta M_t + \beta_4 \Delta A_t + \beta_5 \Delta N_t + \varepsilon_t \tag{39}$$

where the logged difference of the East Asian currency (*C*) is regressed against the logged difference of the US dollar (*U*), the Japanese yen (*Y*), the German mark (*M*), the Australian dollar (*A*) and the New Zealand dollar (*N*). This regression allows weightings to be determined for all currencies tested, including the US dollar, as all currencies are expressed in terms of the Swiss franc. The results from the pre-crisis period (Table 5-1) are similar to those of the original study, with the US dollar prevailing as the dominant regional currency. While the weighting for the US dollar is still significant, Singapore is the currency least tied to the US dollar (85%) during the pre-crisis period, while the other currencies have even higher weightings. In contrast, the Japanese yen has an 11% weighting in the Singapore dollar basket, with other weightings ranging from 3% for the South Korean won to 6% for the Thai baht. In line with the original findings by Frankel and Wei, there is little evidence to support the inclusion of the Australian dollar in the currency baskets during the pre-crisis period, and likewise there is little support for the inclusion of the New Zealand dollar.

However, the currency baskets change significantly in the post-crisis analysis (Table 5-2), notably with the Australian dollar taking a more significant role. The weighting found for the Australian dollar for the now floating Indonesian rupiah is 44%, significantly higher than either the yen (33%) or the US dollar (31%)[34]. There is also evidence for the presence of the Australian dollar in the Malaysian currency basket with a weighting of 17%, again with a higher weighting than the yen (11.5%) although the US dollar remains dominant but diminished (76%). The Australian dollar also has a higher weighting than the yen for South Korea (9.5% vs. 8% for the yen). While Japan has a higher weighting for the remaining currencies, the Australian dollar is still significant in these currency baskets. There is little support for the inclusion of either the yen or the Australian dollar in the currency basket of Taiwan, the US dollar remaining dominant with a weighting of 98%. Overall, the results of this regression analysis indicate that both Australia and Japan have increased their linkages with the Asian currencies, while the influence of the US dollar may have declined over the study period.

Kwan (1996) used a similar method, limiting the model to the Asian currency regressed against the yen and the mark, but using a very limited set of end-of-week data[35] to analyse a specific period of currency change in 1995. The Kwan regression equation was modified here to include the Australian dollar and run in the following form:

$$\Delta C_t = \alpha + \beta_1 \Delta Y_t + \beta_2 \Delta M_t + \beta_3 \Delta A_t + \varepsilon_t \tag{40}$$

where C, Y, M and A are natural logs of the Asian currency, the yen, mark and Australian dollar respectively. The weighting for the US dollar was subsequently determined using the assumption that the weighting for the US dollar was the difference between 1 and the weighting found for the other currencies: i.e. $US = 1 - \beta_1 - \beta_2 - \beta_3$.

[34] Note however that the R^2 value indicates that this result could be subject to misspecification

[35] Kwan (1996) examines 8 months of data in 1995

Table 5-1: Regression Analysis as per Frankel and Wei (1994)

	1 January 1992 – 1 July 1997							
	α (t-statistic)	β_1 USD (t-statistic)	β_2 JPY (t-statistic)	β_3 DMK (t-statistic)	β_4 AUD (t-statistic)	β_5 NZD (t-statistic)	R^2	DW
INDONESIA	0.0001 (4.04)	**1.0351** (50.75)	-0.0032 (-0.51)	0.0024 (0.38)	-0.0232 (-2.66)	-0.0109 (-0.99)	0.9707	2.1497
MALAYSIA	-5.076 E-05 (-0.84)	**0.9497** (27.35)	**0.0455** (4.25)	**0.0593** (5.50)	-0.0163 (-1.10)	-0.0312 (-1.66)	0.9208	1.7773
PHILIPPINES	-7.314 E-06 (-0.06)	**0.8851** (11.69)	0.0025 (0.11)	0.0178 (0.76)	0.0224 (0.69)	0.0714 (1.75)	0.7060	2.0761
SINGAPORE	-8.375 E-05 (-1.56)	**0.8541** (27.69)	**0.1066** (11.19)	**0.0868** (9.06)	-0.0149 (-1.13)	-0.0360 (-2.16)	0.9360	2.3886
SOUTH KOREA	0.0001 (1.54)	**1.0020** (22.55)	**0.0328** (2.39)	-0.0199 (-1.44)	0.0164 (0.86)	-0.0344 (-1.43)	0.8737	1.9848
TAIWAN	7.082 E-05 (0.61)	**0.9544** (14.29)	**0.0563** (2.73)	-0.0366 (-1.77)	0.0187 (0.65)	-0.0155 (-0.43)	0.7461	2.7865
THAILAND	-9.967 E-06 (-0.11)	**0.9290** (17.96)	**0.0647** (4.05)	0.0031 (0.19)	-0.0038 (-0.17)	-0.0149 (-0.53)	0.8309	2.0431

Notes: The Frankel and Wei (1994) regression (39) is run here over the pre-crisis period. The findings here are similar to those of the original study, finding that the US dollar is the dominant regional currency, with the Japanese yen playing a secondary but significant role. Significant statistics are highlighted in bold.

Table 5-2 : Regression Analysis as per Frankel and Wei (1994)

	2 July 1997 – 1 January 2002							
	α (t-statistic)	β_1 USD (t-statistic)	β_2 JPY (t-statistic)	β_3 DMK (t-statistic)	β_4 AUD (t-statistic)	β_5 NZD (t-statistic)	R^2	DW
INDONESIA	0.0005 (0.51)	0.3064 (1.17)	**0.3287** (2.68)	-0.2473 (-1.60)	**0.4453** (3.34)	-0.0312 (-0.26)	0.0538	2.0221
MALAYSIA	-6.526 E-05 (-0.22)	**0.7640** (9.32)	**0.1148** (3.00)	-0.0597 (-1.24)	**0.1718** (4.12)	0.0183 (0.48)	0.3648	2.2715
PHILIPPINES	0.0002 (0.78)	**0.9800** (14.00)	**0.1169** (3.58)	-0.0549 (-1.33)	**0.0735** (2.06)	-0.0069 (-0.21)	0.4784	2.0385
SINGAPORE	5.327 E-05 (0.38)	**0.6529** (17.16)	**0.2309** (13.00)	-0.0025 (-0.11)	**0.1258** (6.51)	-0.0018 (-0.10)	0.7361	2.2031
SOUTH KOREA	-0.0002 (-0.85)	**1.0096** (13.27)	**0.0798** (2.25)	-0.1399 (-3.12)	**0.0945** (2.44)	-0.0071 (-0.20)	0.4059	1.9650
TAIWAN	4.929 E-05 (0.41)	**0.9857** (29.95)	**0.0434** (2.83)	0.0186 (0.96)	0.0138 (0.82)	-0.015 (-0.99)	0.7823	2.3109
THAILAND	-9.486 E-05 (-0.37)	**0.6162** (8.94)	**0.2132** (6.63)	-0.0304 (-0.75)	**0.1616** (4.61)	0.0588 (1.85)	0.4679	1.8298

Notes: The Frankel and Wei (1994) regression (39) is run here over the post-crisis period. The findings here indicate that the US dollar is less dominant than pre-crisis, with the Japanese yen and the Australian dollar both influencing various East Asian currencies. Significant statistics are highlighted in bold

The results, found in Table 5-3, confirm the findings of the Frankel and Wei regression. It reaffirms the observation that, with the exception of Taiwan, less emphasis is being placed on the US dollar in the post-crisis period, with weightings falling in each case. This has occurred despite a general global strengthening of the US dollar during the latter part of the 1990s.

Gan (2000) examines the post-crisis period to determine if a shift in the East Asian currency basket weightings has occurred. Gan uses the following regression to test for the impact of the yen (*Y*) on the East Asia currencies (*C*):

$$\Delta C_t = \alpha + \beta \Delta Y_t + \varepsilon_t$$

(41)

Again this test was estimated using natural logs of the currencies, and was re-estimated by replacing the yen with the Australian dollar. Findings (Table 5-4) are similar to those of previous regressions, with both the Japanese yen and the Australian dollar increasing in relevance in the post-crisis period. This test again confirms that the US dollar has declined in weight, while the yen and the Australian dollar have both increased.

Aggarwal and Mougouè (1996) use the significance of estimated values of β from regressing the difference between the East Asian currency and the US dollar against the difference in the yen and US dollar. An increase in the significance of β, coupled with an increased R^2, indicates that all the regional currencies have increased their relationship with the yen during the latter part of the study (1988 – 1992). To reproduce this regression, the natural logs of the US dollar (*U*) and the Australian dollar (*A*) are expressed in terms of the Swiss franc.

Table 5-3 : Regression Analysis as per Kwan (1995)

	1 January 1992 – 1 July 1997						2 July 1997 – 1 January 2002					
	β JPY	**β DMK**	**β AUD**	R^2	**DW**	**β USD**	**β JPY**	**β DMK**	**β AUD**	R^2	**DW**	**β USD**
IND	-0.0023 (-0.37)	0.0029 (0.45)	-0.0185 (-2.53)	0.0046	2.1472	0.9971	**0.3173** (2.56)	-0.2012 (-1.30)	**0.4325** (3.21)	0.0183	1.9525	0.2502
MLY	**0.0476** (4.49)	**0.0610** (5.68)	-0.0028 (-0.23)	0.0773	1.7743	0.8914	**0.1026** (2.68)	-0.0565 (-1.19)	**0.2009** (4.83)	0.0325	2.1557	0.6965
PHP	-0.0036 (-0.15)	0.0147 (0.63)	-0.0084 (-0.31)	0.0004	2.0782	0.9853	**0.1330** (3.52)	-0.0285 (-0.61)	**0.0913** (2.22)	0.0190	1.8696	0.7756
SNG	**0.1099** (11.68)	**0.0881** (9.23)	0.0006 (0.05)	0.2608	2.3945	0.8013	**0.2120** (12.00)	-0.0120 (-0.55)	**0.1468** (7.64)	0.1915	2.1854	0.6412
SKOR	**0.0360** (2.66)	-0.0186 (-1.35)	0.0312 (1.96)	0.0067	1.9807	0.9328	0.0558 (1.008)	-0.1333 (-1.93)	0.0868 (1.44)	0.0050	1.6701	0.8575
TWN	**0.0594** (2.91)	-0.0372 (-1.80)	0.0254 (1.06)	0.0063	2.7861	0.9153	**0.0457** (2.84)	0.0329 (1.63)	0.0094 (0.53)	0.0133	2.0578	0.9120
THAI	**0.0677** (4.29)	0.0025 (0.15)	0.0026 (0.14)	0.0193	2.0398	0.9272	**0.2048** (5.80)	-0.0261 (-0.59)	**0.1914** (4.98)	0.0643	1.8920	0.6038

Notes: The Kwan (1995) regression (40) is run here over the pre- and post-crisis periods. Both periods mirror the results of the Frankel and Wei study (Table 5-1, Table 5-2), finding that the US dollar has decreased its dominance over the study period, while the Japanese yen and Australian dollar have both become more significant in the post-crisis period. Significant statistics are highlighted in bold.

$$C_t - U_t = \alpha + \beta(A_t - U_t) + \varepsilon_t \tag{42}$$

This is also estimated by replacing the Australian dollar (A) with the yen. Significant values of β are taken to indicate that the currency (yen) is more influential than the US dollar.

Results (Table 5-5) paint the same picture, confirming this chapter's findings in both periods. There is more support for the Australian dollar pre-crisis here, with positive relationships being found with Malaysia, the Philippines and Singapore. In the post-crisis period, the linkages between the East Asian currencies and the Australian dollar have strengthened considerably. There is evidence of a very strong relationship between the Philippines peso and the Australian dollar (a high R^2 and β=1.22), and also the Indonesian rupiah and the Australian dollar (β=2.23). The other currencies all show evidence of a strengthened relationship with the Australian dollar, the weakest evidence being for the South Korean won which has a relatively low R^2. This contrasts significantly with the findings from the previous regressions, and if they are to be interpreted in a similar way to the original findings by Aggarwal and Mougouè, it would appear that the Australian dollar is a more important post-crisis currency than either the US dollar or the Japanese yen.

While there is little evidence from regression analysis to indicate strong links between the Australian dollar and the East Asian currencies in the pre-crisis period, the situation has changed significantly in the post-crisis period, which contains equally strong evidence for the existence of a "koala bloc" as for the existence of a yen bloc.

Cointegration analysis techniques such as those demonstrated by Johansen and Juselius (1990) have become standard practice in the last decade. Zhou (1998) uses cointegration analysis on quarterly data from 1973 - 1993 to look for longer-term trends in the East Asian currencies. Cointegration analysis is performed as per Johansen and Juselius (from herein referred to as the Johansen test, as it is commonly known) to determine further linkages between the yen and other currencies. Aggarwal and Mougouè (1996) likewise use this test, this time to investigate links between the yen and two subsets of the East Asian currencies.

Table 5-6 contains the results of the Johansen test examining cointegration between each East Asian currency and those of Japan, Australia and Germany. The results indicate that while the level of cointegration between the Japanese yen and the East Asian currencies changed and strengthened in the post-crisis period, it is their relationships with the Australian dollar that have undergone the most significant change. Although there is some support for cointegration in the pre-crisis period, the post-crisis period finds evidence of cointegration between the Australian dollar and all currencies other than the Taiwan dollar, while the Japanese yen appears to be cointegrated only with the currencies of Indonesia, Malaysia and South Korea. This differs from the results of the Kwan and Gan regressions, which find little support for a relationship between the yen and the South Korean won. It is significant, however, that this period incorporates the significant structural changes evident in the currencies during the early post-crisis period (late 1997). Other tests that accommodate structural breaks may be more appropriate in this case. It could be argued that the period immediately after the crisis should be removed from the testing period in order to avoid

Table 5-4 : Regression Analysis as per Gan (2000)

	1 January 1992 – 1 July 1997			2 July 1997 – 1 January 2002		
	β* (t-statistic)	R^2	DW	β* (t-statistic)	R^2	DW
IND/JPY	0.0011 (0.22)	0.0000	2.1456	**0.3964** (2.78)	0.0095	1.9399
MLY/JPY	**0.0813** (8.76)	0.0565	1.7647	**0.1452** (3.56)	0.0131	2.1464
PHP/JPY	0.0054 (0.31)	0.0001	2.0773	**0.1520** (4.54)	0.0149	1.8564
SNG/JPY	**0.1582** (10.49)	0.2167	2.3529	**0.2478** (9.34)	0.1495	2.1834
SKOR/JPY	0.0226 (1.91)	0.0029	1.9808	0.0568 (1.34)	0.0010	1.6625
TWN/JPY	**0.0363** (2.46)	0.0033	2.7934	**0.0534** (3.71)	0.0102	2.0492
THAI/JPY	**0.0687** (4.93)	0.0193	2.0397	**0.2499** (5.75)	0.0440	1.8856
IND/AUD	-0.0183 (-2.12)	0.0044	2.1458	**0.4721** (2.84)	0.0120	1.9381
MLY/AUD	-0.0182 (-1.50)	0.0014	1.7811	**0.2159** (4.95)	0.0259	2.1499
PHP/AUD	-0.0091 (-0.25)	0.0001	2.0772	**0.1223** (3.29)	0.0086	1.8554
SNG/AUD	-0.0301 (-2.19)	0.0039	2.2726	**0.2047** (6.16)	0.0911	2.2125
SKOR/AUD	0.0256 (1.75)	0.0018	1.9752	0.0686 (1.27)	0.0013	1.6603
TWN/AUD	0.0166 (0.65)	0.0003	2.7848	0.0310 (1.63)	0.0031	2.0387
THAI/AUD	-0.0115 (-0.63)	0.0003	2.0106	**0.2436** (5.28)	0.0374	1.8989

Notes: * t-values (in brackets) adjusted for heteroskedasticity using White's (1980) procedure. Using this method, Japan seems to be the more inter-related currency in the post-crisis period, while there is little support for either currency affecting the South Korean won. The regression is specified in equation (41. Significant statistics are highlighted in bold.

Table 5-5 : Regression Analysis as per Aggarwal and Mougouè (1996)

	1 January 1992 – 1 July 1997						2 July 1997 – 1 January 2002					
	JPY			AUD			JPY			AUD		
	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2
IND	8.4597	-0.1641	0.1017	7.8980	-0.6815	0.3977	4.2642	**0.9914**	0.0516	7.8675	**2.2348**	0.4
	(139.96)	(-12.74)		(1150.47)	(-30.76)		(7.19)	(7.98)		(209.27)	(30.74)	
MLY	0.7981	**0.0292**	0.0175	0.8827	**0.1711**	0.1362	0.6641	**0.1374**	0.0196	1.1520	**0.3325**	0.1
	(29.43)	(5.05)		(250.24)	(15.03)		(4.90)	(4.84)		(113.11)	(16.88)	
PHP	3.6669	-0.0880	0.0596	3.2066	**0.1561**	0.0426	3.7608	-0.0037	0.0000	3.1259	**1.2205**	0.8
	(84.67)	(-9.53)		(529.02)	(7.98)		(15.87)	(-0.08)		(459.02)	(92.69)	
SNG	-1.0884	**0.3196**	0.3095	0.1731	**0.7788**	0.4165	0.5013	0.0061	0.0001	0.3404	**0.3758**	0.7
	(-18.39)	(25.34)		(22.94)	(31.98)		(6.21)	(0.36)		(96.07)	(54.85)	
SKOR	6.1731	**0.1090**	0.1016	6.7277	-0.1411	0.0386	3.3466	**0.7872**	0.2601	6.9201	**0.3656**	0.0
	(153.63)	(12.73)		(1166.85)	(-7.59)		(18.06)	(20.29)		(407.13)	(11.13)	
TWN	3.7106	-0.0932	0.0802	3.3566	-0.2725	0.1554	1.8394	**0.3428**	0.3170	3.3415	**0.2657**	0.3
	(94.84)	(-11.18)		(645.46)	(-16.24)		(26.20)	(23.31)		(576.75)	(23.72)	
THAI	2.8380	**0.0834**	0.5320	3.2397	-0.0341	0.0201	2.1904	**0.3153**	0.0743	3.3933	**0.5980**	0.4
	(292.58)	(40.36)		(1664.20)	(-5.42)		(14.10)	(9.69)		(343.18)	(31.28)	

Notes: The Aggarwal and Mougouè (1996) regression (42) is run here over the pre- and post-crisis periods. The results find some support for the Australian dollar in both the pre- and post-crisis period, which differs from the results of the previous regressions. The results generally support the findings of Aggarwal and Mougouè in the pre-crisis period., and there is significant support for the Australian dollar in the post-crisis period. Significant statistics are highlighted in bold misspecification problems caused by the structural changes, however it is included here for consistency[36].

Aggarwal and Mougouè (1998) examine the relationship between the Japanese yen and two sets of currencies, defined as the ASEAN economies (Malaysia, Singapore, the Philippines and Thailand) and the Tiger economies (Singapore, South Korea, Hong Kong and Taiwan)[37]. When this technique is replicated, the results indicate that, unlike the Aggarwal and Mougouè study (which focuses on an earlier time period), there is no evidence to support the existence of cointegration between Japan and the systems of ASEAN or Tiger economies in the pre-crisis period (Table 5-7a). The only evidence of cointegration found in the pre-crisis period is of one cointegrating relationship between the Australian dollar and the ASEAN economies. The post-crisis period sees the presence of two cointegrating relationships indicated between the ASEAN economies and both Germany and Japan. However, the likelihood ratio for the Australian dollar indicates that there are three cointegrating relationships between Australia and the ASEAN economies. The only evidence of cointegration with the Tiger economies is for Germany in the post-crisis period. Neither Australia or Japan have any support for cointegration with the Tiger economies using this method of testing. Cointegrating vector estimates are given in Table 5-7b and Table 5-7c.

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[36] When the post-crisis period is shortened to 1 January 1998 – 1 January 2002, the Australian dollar still shows the greatest level of cointegration with the East Asian currencies. Results available on request.
[37] For the purposes of this study, Hong Kong has been omitted from the Tiger group and all currencies are quoted in US dollar terms

Table 5-6 : Johansen Cointegration Analysis as per Zhou (1998)

	1 January 1992 – 1 July 1997			2 July 1997 – 1 January 2002		
	AUD	**JPY**	**DMK**	**AUD**	**JPY**	**DMK**
INDONESIA	**26.7864**[a]**	**26.8274**[a]**	**27.2691**[a]**	**16.9094*[b]**	**32.0348**[b]**	**13.7894**[b]**
MALAYSIA	**19.1925*[b]**	13.7162	14.9478	**29.8683**[b]**	**37.4006**[b]**	30.7026
PHILIPPINES	9.0531	7.3133	9.0695	**23.5386**[b]**	3.4443	13.7425
SINGAPOARE	6.8969	11.4361	3.6397	**15.4889*[b]**	6.2365	9.6561
SOUTH KOREA	5.4187	7.3814	7.1446	**16.8821*[b]**	**18.0690*[b]**	**15.6315*[b]**
TAIWAN	7.7210	4.0850	3.3200	8.3966	10.6130	**25.3593*[c]**
THAILAND	**16.9539*[b]**	**28.4800**[b]**	**20.0933**[b]**	**17.3563*[b]**	7.9828	14.9022

* Significant at 5%
[a] No deterministic trend, no intercept or trend
[c] Linear trend, intercept and trend

** Significant at 1%
[b] Linear trend and intercept

Notes: Johansen cointegration analysis finds support for the influence of the Australian dollar in both the pre- and post-crisis periods. It is notable that this has increased post-crisis, and also that the cointegration testing finds evidence for a relationship between the Australian dollar, the yen and the South Korean won, which is lacking in the previous regression analysis. Cointegration analysis also finds more support for the German mark as a currency of influence in the post-crisis period. Significant statistics are highlighted in bold.

5.4 Conclusion

Several researchers have raised the possibility that a yen bloc has emerged in the East Asian region during the 1990s. The emergence of this bloc has been attributed to the increasing investment flows between Japan and East Asia, both in the form of direct and indirect investment, government assistance and through tourism and trade. However, few researchers have looked further to see if other major economies in the Asia-Pacific region play an equally significant role in East Asia. By reproducing the methodologies used in previous studies, this chapter indicates that there is strong evidence to show that the Australian dollar is influential in the currencies of post-crisis East Asia. Support for the Australian dollar as a related currency is at least as strong as that for the yen in the period subsequent to the Asian currency crisis. It is evident that the Australian dollar is emerging as a currency of regional importance. Further, there is also evidence that the strength of the yen relationship may not be as significant as it seemed.

Many East Asian currencies underwent some form of structural change during the 1997 East Asian financial crisis. An important point to note is that the cointegration analysis techniques used here avoided potential problems caused by such changes by breaking the study into pre- and post-crisis periods, based on Gan (2000). Standard implementations of statistics such as the Johansen cointegration test fail to take structural breaks into account and these problems are avoided by using sub-periods rather than attempting a full-period analysis. A further investigation, using more suitable techniques, is undertaken in Chapter 6. Further, the increased levels of cointegration between these regional currencies is particularly relevant in regard to currency cross-hedging. The Australian dollar has a variety of liquid, exchange-traded derivatives available on world markets and the results of this chapter would indicate that

Table 5-7a: Johansen Cointegration Analysis as per Aggarwal and Mougoué (1998)

		1 January 1992 – 1 July 1997				2 July 1997 – 1 January 2002			
	H_0	MLY, PHP, SNG, THAI (ASEAN)		SKOR, SNG, TWN (Tigers)		MLY, PHP, SNG, THAI (ASEAN)		SKOR, SNG, TWN (Tigers)	
		Johansen Likelihood Ratio	Eigenvalue	Johansen Likelihood Ratio	Eigenvalue	Johansen Likelihood Ratio	Eigenvalue	Johansen Likelihood Ratio	Eigenvalue
	r = 0	**75.6626***	0.0252	30.9079	0.0144	**119.1646****	0.0490	46.3583	0.0216
	r <= 1	32.2136	0.0092	10.1298	0.0062	**66.8003****	0.0344	23.5663	0.0140
AUD	r <= 2	16.4633	0.0055	1.1797	0.0008	**30.3507***	0.0166	8.8997	0.0064
	r <= 3	6.5948	0.0040	0.0643	0.0000	12.9389	0.0122	2.2512	0.0022
	r <= 4	0.6741	0.0017			0.1711	0.0002		
	r = 0	65.8642	0.0252	34.9746	0.0160	**99.7361****	0.0490	47.0848	0.0201
	r <= 1	29.3742	0.0092	11.9479	0.0056	**47.3741***	0.0259	25.9035	0.0132
JPY	r <= 2	16.1035	0.0055	3.9613	0.0027	20.0083	0.0144	12.0912	0.0105
	r <= 3	8.1684	0.0040	0.0497	0.0000	4.9438	0.0045	1.0806	0.0010
	r <= 4	2.4477	0.0017			0.2321	0.0002		
	r = 0	50.4698	0.0151	25.9035	0.0130	**103.3083****	0.0476	**55.6731****	0.0236
	r <= 1	28.6415	0.0112	7.2182	0.0043	**52.5214***	0.0278	**30.7524***	0.0153
DMK	r <= 2	12.5512	0.0062	1.0670	0.0007	23.1643	0.0144	14.6402	0.0088
	r <= 3	3.6389	0.0025	0.0661	0.0000	8.0306	0.0066	**5.4805***	0.0052
	r <= 4	0.0973	0.0001			1.1657	0.0011		

* Rejects the null at 5% ** Rejects the null at 1%

Notes: Unlike the original study, there is little support here for the cointegrating systems in the pre-crisis period. There is more support for this in the post-crisis period, particularly between the "tiger" currencies and the OECD currencies. Significant statistics are highlighted in bold.

Table 5-7b and 5-7c: Johansen Cointegration Analysis Cointegrating Equations (ASEAN and Tigers) as per Aggarwal and Mougouè (1998)

Cointegrating Equations (ASEAN)											
1 January 1992 – 1 July 1997						2 July 1997 – 1 January 2002					
JPY	**MLY**	**PHP**	**SNG**	**THAI**	**C**	**JPY**	**MLY**	**PHP**	**SNG**	**THAI**	**C**
1.0000	1.2278 (0.62)	0.6529 (0.32)	0.5231 (0.24)	-10.0446 (1.34)	24.6895	1.0000	-8.9487 (3.48)	-0.7029 (0.72)	-3.1251 (2.07)	2.0616 (1.20)	3.9444
AUD	**MLY**	**PHP**	**SNG**	**THAI**	**C**	**AUD**	**MLY**	**PHP**	**SNG**	**THAI**	**C**
1.0000	-0.0345 (0.30)	-0.5685 (0.15)	-0.8071 (0.11)	3.4505 (0.58)	-9.2344	1.0000	1.2279 (0.40)	-0.8576 (0.15)	0.9450 (0.53)	-0.2101 (0.19)	1.3285
DMK	**MLY**	**PHP**	**SNG**	**THAI**	**C**	**DMK**	**MLY**	**PHP**	**SNG**	**THAI**	**C**
1.0000	-5.2172 (5.60)	-0.7007 (1.15)	-0.5008 (0.86)	12.1869 (16.20)	-32.4395	1.0000	4.9843 (1.51)	-0.0286 (0.38)	1.3111 (1.23)	-1.4594 (0.58)	-2.5581

Cointegrating Equations (Tigers)									
1 January 1992 – 1 July 1997					2 July 1997 – 1 January 2002				
JPY	**SKOR**	**SNG**	**TWN**	**C**	**JPY**	**SKOR**	**SNG**	**TWN**	**C**
1.0000	-2.1754 (0.62)	-0.4029 (0.44)	2.1885 (0.94)	2.8529	1.0000	1.3835 (1.05)	1.9987 (1.29)	-4.5113 (2.05)	0.0109
AUD	**SKOR**	**SNG**	**TWN**	**C**	**AUD**	**SKOR**	**SNG**	**TWN**	**C**
1.0000	0.6771 (0.32)	-1.1140 (0.25)	-1.4763 (0.52)	0.4581	1.0000	-1.5919 (0.89)	-4.3906 (1.40)	2.4763 (1.68)	4.5686
DMK	**SKOR**	**SNG**	**TWN**	**C**	**DMK**	**SKOR**	**SNG**	**TWN**	**C**
1.0000	-1.0077 (0.2322)	-0.9127 (0.17)	-0.6394 (0.34)	8.7577	1.0000	-1.0915 (0.46)	-4.4338 (0.91)	3.6162 (1.16)	-3.0980

these derivatives may be suitable products to use in East Asian currency hedging strategies. This is examined further in Chapter 7.

Not only is Australia a major regional economy, the strength of which is reflected in the levels of integration between the East Asian and Australian currencies, but it can be argued that the currency is now equally important, perhaps more so, than the yen. A "koala bloc" is therefore a feature of the East Asian economies that had previously not been identified. As Australia increases its role in Asia, and with the relative strength of the Australian economy at the start of the early 21st century, regional integration can be expected to increase as global economies become increasingly interrelated.

6 Cointegration In The Presence of Structural Breaks

In any study of hedging, it is vital to ascertain the nature of the relationship between the underlying asset and the derivative instrument with which it is being hedged. The more closely linked these are, the more effective the hedge (Eaker and Grant, 1987). While the presence of cointegration introduces problems of its own[38], if the asset and the hedging instrument are cointegrated, the hedge is likely to be effective. When attempting a cross-hedge, it is essential to determine the closeness of the relationship between the asset to be hedged and the asset underlying the derivative product being used in the cross-hedge. Hence the study of cointegration between East Asian currencies and OECD currencies with exchange-traded futures allows the determination of the most effective futures to use when forming a cross-hedge. This chapter looks particularly for linkages between regional currencies, namely the Japanese yen and the Australian dollar, and the East Asian currencies affected by the 1997 crisis.

The time period studied here is likely to incorporate structural changes during the 1997 East Asian crisis period, meaning that traditional cointegration and unit root testing methods may not be applicable as they fail to accommodate structural change. Alternative tests for cointegration are examined here, which may be more suitable to use when studying time series data over periods of structural change.

6.1 Introduction

Frankel (1993) commented on the formation of a yen bloc in East Asia, stating that "Japan is forming an economic bloc … by means of such instruments as flows of aid,

[38] See the discussion of error-correction models in Chapter 2.

foreign direct investment, and other forms of finance, to influence its neighbours' trade toward itself"[39]. Chapter 5 explored the issue of the yen bloc further, and some of the studies discussed in that chapter use the Johansen test for cointegration to verify the existence and strength of relationships between regional currencies and the yen (Frankel, 1993; Aggarwal and Mougouè, 1996). Chapter 5 found evidence to suggest that Australia is also a significant factor in regional economic dynamics, and this chapter will focus on the use of cointegration tests to further draw out the nature of intraregional currency relationships.

The 1997 crisis resulted in changes in monetary policy throughout East Asia, and significant economic realignment took place during and after the crisis. As a result, it can be anticipated that the behaviour of Asian currencies changed significantly, and this was indicated in Chapter 5. The development of the Zivot and Andrews (1992) test for a unit root and the Gregory and Hansen (1996) test for cointegration, both of which accommodate a structural break, may allow a more accurate picture of the relationship between currencies to be developed. Granger et al (2000) used these tests to look for relationships between the currencies and stock markets of the region, acknowledging the relevance of these tests when examining a period of structural change.

This chapter examines the currencies of the seven East Asian economies used in this thesis and their relationship with two near-neighbour developed economies, the Japanese yen and the Australian dollar, and one non-neighbour developed economy currency, the German mark. Japan and Australia have strong economic relationships with the countries in East Asia through trade and locality, and hence it is possible that their currencies possess a degree of correlation reflecting the close relationships within

[39] Frankel (1993) p.54

the region. Germany, however, is not regionally located and has weaker trading ties with Asia, so it is anticipated that it can act as a "control" with which to contrast the strength of the findings for Japan and Australia. This chapter finds that the influence of Japan has weakened since the 1997 crisis, and that the Australian dollar has become a currency of equal, if not greater, regional influence than the Japanese yen. As Australia increases its cultural and trading ties with Asia, it is anticipated that this trend may continue. These findings will have an impact on issues such as cross-hedge instrument selection (see Chapter 7) and asset allocation strategies.

6.2 Method

Baillie and Bollerslev (1989) note that "a general consensus has emerged in recent years that many macroeconomic time series ... can be characterised by a stochastic trend model ... similarly, it has long been recognized that many financial time series, such as foreign exchange rates, are nonstationary"[40]. As discussed in section 2.6, it is well established in the literature that exchange rates are difference stationary processes, they often contain unit roots, and they exhibit time-dependent heteroskedasticity. These properties are assumed, and testing for characteristics will proceed from these assumptions.

Dickey and Fuller (1979, 1981) proposed a test statistic that characterises a time series as having a unit root. This statistic has become an accepted part of the literature relating to time series, and is widely used to characterise currencies[41]. The Augmented Dickey Fuller (ADF) test is modelled such that :

[40] Baillie and Bollerslev (1989a), p. 167

[41] see, for example, Granger et al (2000) and Aggarwal and Mougouè (1996)

$$\Delta y_t = \alpha + \beta t + (\rho - 1) y_{t-1} + \sum_{i=1}^{k-1} \theta_i \Delta y_{t-i} + \varepsilon_t$$

(43)

where $\alpha + \beta t$ represents the constant and slope terms,

ε is a white noise term (*iid* $(0,\delta^2)$)

with null hypothesis $H_0 : \rho = 1$. Section 2.6.1.1 discusses the ADF test in more detail. As noted there, the ADF technique does not allow for a structural break in the time series data and may not accurately characterise data when the period examined contains such a break, as occurred during the Asian currency crisis, resulting in the null hypothesis being accepted or rejected inappropriately. Another drawback of the ADF test is that it assumes that error terms are *iid*. This restriction may not be appropriate with currency data, and Phillips and Perron (1988) developed a test based on the Dickey-Fuller (1979) test that eases some of the restrictions on the error term of the model (see section 2.6.1.2 for more detail on the Phillips and Perron test). The test allows the errors to be weakly dependent and heterogeneously distributed. Both the Phillips-Perron (PP) and ADF tests are commonly used in currency analysis[42] - Baillie and Bollerslev (1989a) among others have used the PP test to show that foreign exchange data can be characterised as *I(1)* processes. However, the PP test also fails to accommodate time series incorporating a structural break.

Zivot and Andrews (1992) derived an alternative statistic that allows the ADF test to adjust for structural breaks in the data. Based on Perron and Vogelsang (1992), who introduced a dummy variable to the ADF statistic to adjust for critical values, the Zivot and Andrews (ZA) method avoids the dummy variable problems of perfect information where the dummy variable is set depending on the point at which the structural break is

[42] see, for example, Corbae and Ouliaris (1996) and Baillie and Bollerslev (1989a)

believed to occur. Instead, the regression is run through a series of iterations to determine the most likely break based on the value of the coefficient δ that generates the smallest valued t-statistic, and hence gives the least support for the existence of a unit root. The regression model used is the level shift with trend model, as per Granger et al (2000), and is discussed in more detail in section 2.6.1.4. The model is given as:

$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \gamma DU_t(\lambda) + \sum_{i=1}^{k} \theta_i \Delta y_{t-i} + a_t \tag{44}$$

where $DU_t(\lambda)$ = 1 for t > Tλ,

= 0 otherwise

and λ = Tb/T with Tb being the point of the structural break.

The Zivot and Andrews method avoids the risks associated with arbitrary period selection by empirically determining the existence and position of structural breaks in the series. Lag terms are determined empirically based on the significance of the coefficient θ_i, working backwards from a maximum lag count of 15. The appropriate number of lags is determined to exist when the value of i is chosen such that the t-statistic of θ_i is greater than 1.6 in absolute value, and the statistic for θ_{i+n} for n>0 is less than 1.6. The success of the unit root hypothesis is determined using critical values generated for the value of λ estimated in each case. The Zivot and Andrews (1992) critical values are shown alongside the results for each currency.

6.2.1 Regional Cointegration

The East Asian currencies were generally regarded to be pegged in some form before the currency crisis of 1997. While the exact method of determining the peg is not disclosed by individual governments, these pegs are generally assumed to be based on some basket of currencies, and Chapter 5 estimated the composition of these baskets and the role of the yen in determining the final pegged value. However, cointegration testing is more appropriate for use in the post-crisis period, when many of the currencies moved to less managed regimes and currency baskets are no longer the norm in East Asia.

A number of studies have already used cointegration testing to characterise the relationships between currencies in East Asia. Zhou (1998) examined a number of East Asian currencies and found evidence for linkages between the Japanese yen and the Taiwan dollar, the Singapore dollar and the Thai baht for the period 1973 – 1993 using regression analysis and the Johansen (1988) test for cointegration. The Johansen test identifies the estimated coefficient matrix Π and works with this to determine the relationship between vectors, identifying up to $k-1$ cointegrating relationships. Johansen posits that working with the estimators allows the error structure of the underlying time series data to be incorporated into the testing, whereas regression estimates fail to do this. Further work by Osterwald-Lenum (1992) derived critical values for the reduced-rank test used in this chapter. However, it is anticipated that the presence of structural breaks may cause the Johansen test to give an inaccurate result when applied without the inclusion of dummy variables to adjust for these structural breaks. Since such variables would need to be included explicitly, with the benefit of full hindsight, they may not be the most appropriate way to test in general circumstances. When left unadjusted, the test assumes a time-invariant cointegrating vector which will not be the case should a structural change occur during the time period examined.

The Gregory and Hansen (1996) test for cointegration expands on previously developed tests for cointegration, such as the Johansen test, to enable testing over periods incorporating structural breaks and includes the independent derivation of an appropriate breakpoint. The test is based on a regime switching methodology, whereby a residual-based test for cointegration is used which allows for a regime shift in the intercept alone or in the entire coefficient vector. Like the Zivot and Andrews (1992) test for a unit root, the selection of breakpoints for the structural change is done empirically, hence again removing the possibility of arbitrary period selection. The Gregory and Hansen (GH) test may therefore be regarded as a multivariate extension of the univariate Zivot and Andrews test, and is discussed more fully in section 2.6.2.2.

The GH test is broken up into two stages. Again the level shift with trend model is used as per Granger et al (2000), such that

$$y_{1t} = \alpha + \beta t + \gamma DU_t(\lambda) + \theta_1 y_{2t} + \varepsilon_t \tag{45}$$

where y_{1t}, y_{2t} are $I(1)$ time series,

$DU_t(\lambda) = 1$ for $t > T\lambda$,

$= 0$ otherwise, as per the ZA test,

and $\lambda = Tb/T$ with Tb being the point of the structural break.

Standard ADF and PP tests are then run against the residuals to determine if they are *I(0)* or *I(1)* processes. If the residuals are *I(0)* processes, this indicates the presence of cointegration between y_{1t} and y_{2t} and hence the null hypothesis of no cointegration can be rejected. Again the structural break is empirically determined, in this case by finding the value of λ that generates the smallest ADF and/or PP test statistic.

6.3 Results

This chapter looks explicitly at intra-regional currency relationships in the Asian region, examining the relationship between the two largest OECD economies neighbouring East Asia, Australia and Japan, and the newly industrialised and developing economies of East Asia (Indonesia, the Philippines, Malaysia, Singapore, Thailand, Taiwan and South Korea). It uses the German mark as a "control" currency, being a major non-regionally-related currency that has lesser but still significant trading relationships with East Asia. Data is taken from the set described in Chapter 4, but was broken into sub-periods for examination when using techniques that do not accommodate structural breaks in the time series. The pre-crisis sub-period runs from 01/01/1993 to 30/05/1997 and the post-crisis sub-period runs from 01/01/1998 to 01/01/2002. The sub-periods were specifically chosen to eliminate the period of greatest currency volatility (late 1997), which, as noted previously, may interfere with the non-break-accommodating methods used in this analysis. This should allow more accurate statistics to be generated from the period surrounding the crisis, and can be used for comparison with full-period break-accommodating methods.

Initially, unit root testing is done using the established Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) statistics, which do not adjust for structural breaks and therefore may misspecify data during this period of regime change. The results, found in Table 6-1, show testing across the full period as well as the sub-periods prior and subsequent to the regime shifts. Full period testing indicates that all the exchange rates examined are *I(1)* as both the PP and ADF tests fail to reject the null hypothesis of a unit root using the McKinnon (1991) critical values and default lag terms[43]. However, as these tests do not accommodate the significant structural break that occurred in 1997, the results are broken into sub-periods for confirmation, and the sub-period unit root tests yield somewhat different results. Testing over the pre-crisis period finds evidence of a unit root in all currencies, with only the Indonesian rupiah being rejected by the PP test. Considering the moderate power of this test (5%), and the fact that the ADF test fails to reject the null hypothesis, it is reasonable to accept the null hypothesis in this instance. In contrast, the post-crisis period rejected the null hypothesis of a unit root in several currencies. Indonesia, Malaysia and Singapore show little support for a unit root in the post-crisis sub-period, with both the PP and ADF tests rejecting the null hypothesis. While the full period results indicate unit root processes in all cases, the sub-period results tell a different story. The ADF and PP tests may not be appropriate tests for a unit root when dealing with periods of structural change, as they fail to find any support for the rejection of a unit root over the full period while showing that during at least one sub-period the unit root hypothesis is rejected for several currencies. These currencies are found to contain a unit root before the crisis, but appear to have changed in structure after the crisis. However, the Zivot and Andrews (1992) test does adjust for the presence of structural breaks, and therefore may provide a more consistent picture for the overall period. The results, found in Table 6-2, are more in keeping with the latter sub-period findings of the ADF and PP tests, rejecting the null of a unit root for Indonesia and Malaysia across the full period. It is interesting to note that while the results for Singapore do not reject the unit root hypothesis, the results for South Korea

[43] Lag terms provided by E-views. Changes to the number of lag terms made no material difference to the results. Default lag terms were typically 4 for the ADF test, and for the PP test there were typically 8 lags for the full period and 6 for each sub-period.

and Thailand do reject the null of a unit root. This contrasts with the full period ADF and PP results, which accept the null of the unit root for all currencies.

The results of the Zivot and Andrews test also finds evidence of structural breaks taking place between June 27, 1997 (Thailand) and December 31, 1997 (Indonesia), the period generally held to encompass the currency crisis (and the period omitted in the pre- and post-crisis sub-period breakdowns). Interestingly, the breakpoints vary a little from the IMF regime change statistics, but correspond with those likely to be identified by a visual inspection of the currency (Figure 6-1 and Figure 6-2). While Indonesia is regarded as having moved to a floating regime in August 1997, the value of the rupiah remained relatively stable until December, when the rupiah began to experience very large changes in value. The Zivot and Andrews test identifies the end of December as the breakpoint in the rupiah. The breakpoints for the other regime changing currencies are identified by the Zivot and Andrews test slightly before their "announced" change (late October for South Korea vs. a December announcement, late June for Thailand vs. a July announcement).

Evidence of the existence of causal relationships between currencies is sought using the Granger (1969) causality test. While the Granger causality test may indicate a relationship between the currencies, it is often emphasised that this does not imply the existence of a relationship, rather the potential for the existence of a relationship. Tests for the hypothesis that the developed economy currencies "Granger-cause" East Asian currencies (Table 6-3a) yield some interesting results. Against the null hypothesis that the developed economy currencies do not Granger-cause East Asian currencies, we find that we can reject this hypothesis for Australia and all currencies except the Thai baht at

Table 6-1: Unit Root Tests for Currencies – ADF and PP Tests

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	S. KOREA	TAIWAN	THAILAND	AUSTRALIA	GERMANY	JAPAN
Full Period										
ADF Level	-2.7934	-2.0787	-1.7641	-2.1362	-2.0005	-1.5878	-2.1642	-1.9720	-2.1375	-2.3742
PP Level	-2.6038	-1.9471	-1.7225	-1.9670	-2.1132	-1.7334	-2.1639	-1.8663	-2.0797	-2.3671
Pre-Crisis										
ADF Level	-3.1082	-2.0791	-2.3391	-0.5160	0.8329	-2.0121	-2.1407	-2.2603	-1.0149	-2.1520
PP Level	**-3.5653****	-2.1066	-3.0441	-0.4841	0.6401	-2.8410	-1.8870	-2.5206	-0.9586	-2.0600
Post-Crisis										
ADF Level	**-3.5905****	**-5.7590***	-2.0271	**-3.5317****	-2.7522	-1.0290	-3.0924	-2.3114	-2.4074	-1.0646
PP Level	**-3.5498****	**-5.6943***	-2.1409	**-3.5488****	-2.7875	-1.0102	-3.0080	-2.3894	-2.4434	-1.1482

* Trend and intercept, rejects at 1%   ** Trend and intercept, rejects at 5%

Notes: Pre-crisis period is 1/01/1993 – 5/30/1997, post-crisis period is 1/01/1998 – 1/01/2002. These periods have been chosen to exclude the structural breaks that occurred in the latter part of 1997. The ADF test used 4 lags, while the PP test used 8 for the full period, 6 pre-crisis and 6 post-crisis. All tests used trend and intercept specifications. Significant statistics are highlighted in bold.

the 1%, 5% or 10% level of significance. This provides support for the proposal that there are indeed relationships between the Australian dollar and the East Asian currencies, other than the Thai baht.

Similarly, there is evidence of a Granger-causal relationship between the currencies of Japan and the Philippines, South Korea and Taiwan at 1%, and between the currencies of Japan and Malaysia, Indonesia and Singapore at 10%. The German mark is significant at 1% with the currencies of the Philippines, Singapore and Taiwan, at 5% with the currencies of Indonesia and South Korea, and at 10% with the Thai Baht. Table 6-3b contains the results for the opposite causality (East Asian currencies "Granger-cause" developed economy currencies). The results here are of great interest. As could be anticipated, there is no evidence of any causal relationship between the East Asian currencies and that of Germany. There are indications of causality between the currencies of both South Korea and Indonesia and the Japanese yen, while the East Asian relationship with Australia is closer again, with support for the hypothesis that the East Asian currencies of the Philippines, South Korea, Taiwan and Thailand Granger-cause the Australian dollar. The interaction between Japan, Australian and several East Asian currencies appears from this test to work both ways – an important observation and one that signals close ties between these economies.

The results for the Johansen cointegration test (Table 6-4) fail to find strong evidence of cointegration between most currencies across the full study period[44]. Only the Philippines generates a significant statistic for cointegrating relationships with Australia and Germany, and Taiwan is the only currency with a full-period cointegrating

[44] Unless stated otherwise, one lag in the levels is used.

Table 6-2: Unit Root Tests for Currencies – Zivot and Andrews Test

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	S. KOREA	TAIWAN	THAILAND
T-Statistic	-5.2886*	-6.9758*	-3.1461	-3.4769	-4.1828**	-3.5974	-5.4249*
λ	0.5554	0.5111	0.5026	0.5026	0.5341	0.5319	0.4987
Date of Break	12/31/1997	8/07/1997	7/10/1997	7/10/1997	10/22/1997	10/15/1997	6/27/1997
Number of Lags	11	10	7	11	9	5	9

* Significant to 1% ** Significant to 5%

Notes: The Zivot and Andrews (1992) statistic indicates the presence of structural breaks in all East Asian currencies during the crisis period. In keeping with observations, Thailand experiences its break first (see Figure 5-1), while Indonesia is the last to readjust (Figure 5-2). The results for OECD currencies (not included here) failed to reject the null hypothesis of a unit root, and there was no evidence of a breakpoint found for Germany. Australia was found to have a breakpoint during the East Asia crisis period (10/10/1997) but the breakpoint identified for Japan was outside the crisis period (2/05/1996).

Table 5-3a : Zivot and Andrews calculated t-statistics

λ	1%	5%	10%
0.1	-4.27	-3.65	-3.36
0.2	-4.41	-3.80	-3.49
0.3	-4.51	-3.87	-3.58
0.4	-4.55	-3.94	-3.66
0.5	-4.55	-3.96	-3.68
0.6	-4.57	-3.95	-3.66
0.7	-4.51	-3.85	-3.57
0.8	-4.38	-3.82	-3.50
0.9	-4.26	-3.68	-3.35

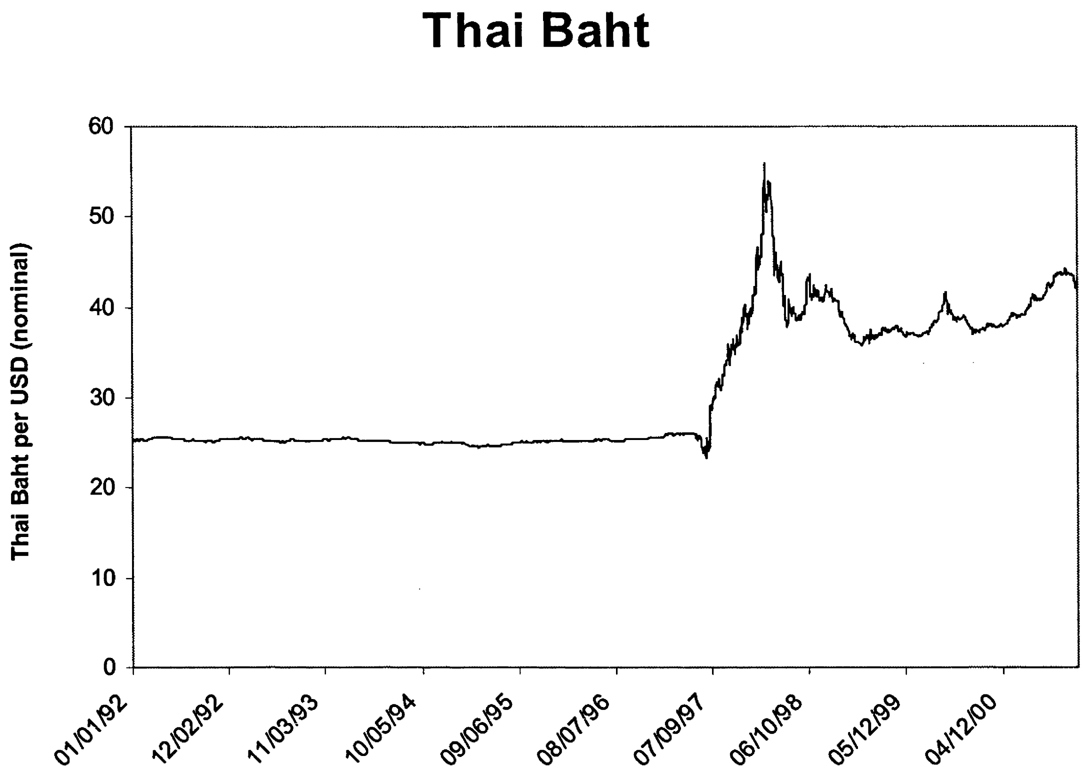

Figure 6-1: Nominal Currency Graph of the Thai Baht 1992 - 2000

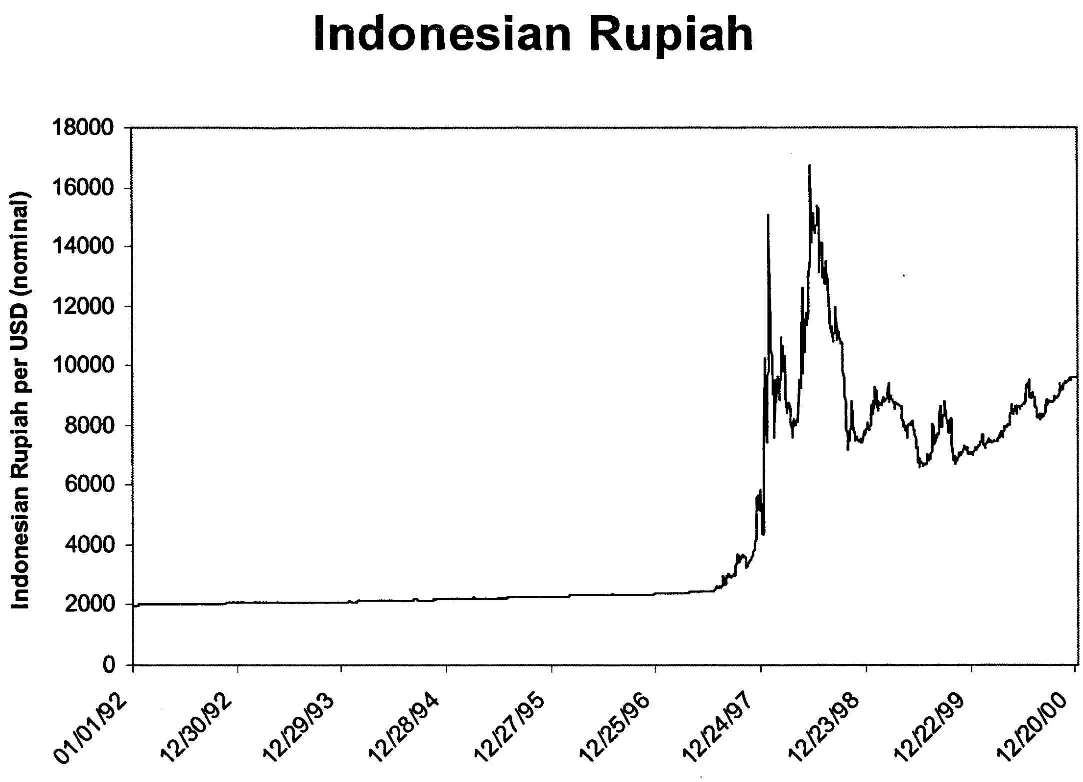

Figure 6-2: Nominal Currency Graph of the Indonesian Rupiah 1992 - 2000

relationship with Japan. However, when the period is broken down into the pre/post-crisis sub-periods, the results are quite different, and somewhat inconsistent. Of the three relationships identified during the full period, only one (that between Australia and the Philippines) is evident in both periods. The Japan/Taiwan relationship is evident only in the pre-crisis period, while the Germany/Philippines relationship is evident only in the post-crisis period. However, several relationships are found in both the pre- and post-crisis periods that are not indicated in the full period results.

Relationships between Indonesia and both Australia and Japan are found in each of the two sub-periods, as is a cointegrating relationship between Singapore and Japan. South Korea is also found to have cointegrating relationships with both Australia and Japan in each sub-period. It is surprising that while the sub-periods indicate cointegration, the full period results do not. However, the Johansen test has not been adjusted to accommodate structural breaks, and from the use of the sub-periods it may be surmised that it is the period incorporating the structural break that could be causing this dichotomy. The Gregory and Hansen (1996) test for cointegration may be more appropriate for full-period testing, as it is known that significant structural change took place in the East Asian currencies during this time. The results of the Gregory and Hansen test (Table 6-5) identify a cointegrating relationship between Australia and both Indonesia and the Philippines, as was suggested by the Johansen sub-period results, as well as identifying a cointegrating relationship between Australia and Malaysia. Likewise it identifies a relationship between Japan and Indonesia, and Japan and South Korea, which were also identified in Johansen sub-period results. It further identifies a cointegrating relationship between Japan and Taiwan, as did the Johansen full-period results, and it additionally identifies a relationship between Japan and Malaysia. There

Table 6-3a: X (Developed economy currency) does not Granger cause Y (Asian currency)

	AUSTRALIA	GERMANY	JAPAN
	F	F	F
INDONESIA	**3.8254****	**4.1641****	**2.9325^**
MALAYSIA	**2.4625^**	1.1883	**2.8673^**
PHILIPPINES	**13.8619***	**8.1726***	**8.3076***
SINGAPORE	**5.8068***	**8.2447***	**2.8377^**
SOUTH KOREA	**3.2413****	**3.0352****	**9.6914***
TAIWAN	**5.6887***	**13.0507***	**21.9302***
THAILAND	1.2610	**2.8296^**	0.7371

Table 6-3b. Y (Asian currency) does not Granger cause X (Developed economy currency)

	AUSTRALIA	GERMANY	JAPAN
	F	F	F
INDONESIA	1.5645	0.2576	**2.4827^**
MALAYSIA	2.0552	0.5621	0.5530
PHILIPPINES	**4.4881****	0.5027	1.1427
SINGAPORE	1.3671	0.1092	1.4298
SOUTH KOREA	**2.5475^**	0.6479	**3.3704****
TAIWAN	**5.8304***	0.0425	1.8333
THAILAND	**2.5026^**	0.6168	1.5088

* Rejects at 1% ** Rejects at 5% ^ Rejects at 10%

Notes: Two lags used for all calculations. Significant statistics are highlighted in bold. Granger Causality testing used two lags in each case. The results indicate that there is a bi-directional relationship between the Australian and East Asian currencies, with causal relationships being significant in both Table 5-4a and Table 5-4b. There is some support for bidirectional relationships in the case of Japan and both South Korea and Indonesia, while there is no evidence of any East Asian currency influencing the German mark. In contrast, there is some support for Granger causality in the opposite direction, with all OECD currencies supporting Granger causality with some East Asian currencies.

are no Johansen test results for Germany that are consistent in both the pre- and post-crisis periods, but the Gregory and Hansen identifies cointegrating relationships between Germany and Indonesia (Johansen pre-crisis), Malaysia (Johansen post-crisis), and Singapore (Johansen pre-crisis). Interestingly, the full-period Johansen result of a cointegrating relationship between Germany and the Philippines is not evident from the Gregory and Hansen results.

Breakpoints from the Gregory and Hansen test indicate structural changes between most currencies occurred during the Asian currency crisis period of June to December 1997. The structural break in the Indonesian rupiah is identified as occurring about a month after that predicted by the Zivot and Andrews test (late January 1998, as opposed to late December 1997), as are the breaks in the Thai baht and the Singapore dollar. There is some variability between these breakpoints and those of the Zivot and Andrews test as the Gregory and Hansen breaks are identified relative to the developed economy currency, rather than as determined by the East Asian currency movement in terms of US dollars as is the case with the Zivot and Andrews test.

It is interesting to note that the cointegration test results indicate a similar number of countries may be linked to both the Australian dollar and the German mark as are linked to the Japanese yen. While a yen bloc may be present, there also seems to be evidence for a "koala bloc" and indeed a significant European influence. This may be indicative of the economic decline suffered by Japan over the 1990s, and the emergence of other nations as important trading partners may be reflected in the closer ties between the East Asian currencies and the other developed economy currencies that were not so evident in pre-crisis East Asia. The yen bloc, much discussed in the literature of the early 1990s,

Table 6-4: Johansen Test for Cointegration

	INDONESIA	MALAYSIA	PHILIPPINES	SINGAPORE	S. KOREA	TAIWAN	THAILAND	AUSTRALIA	GERMANY	JAPAN
Full Period										
Australia	-	-	29.1289**^{1a}	-	-	-	-		-	-
Germany	-	-	15.4649**^{1b}	-	-	-	-	-		-
Japan	-	-	-	-	-	17.5447*^{1a}	-	-	-	
Pre-Crisis										
Australia	20.8596*^{2c}	-	18.3312**^{3a}	13.5388**^{2c}	13.7706**^{2c}	-	-		-	-
Germany	20.0964*^{2c}	-	-	15.2888**^{2c}	-		-	-		-
Japan	26.7825*^{2b}	-	-	20.7955**^{2b}	23.4650*^{2b}	19.3566**^{1b}	19.6862**^{1b}	-	-	
Post-Crisis										
Australia	43.7251*^{1a}	42.2231*^{1a}	23.3397*^{1b}	-	16.1758**^{1b}	-	17.0305**^{1b}		-	-
Germany	-	39.8882*^{1a}	13.8892**^{2c}	-	-	-	13.1098**^{2c}	-		-
Japan	39.1363*^{1a}	41.9501*^{1a}	-	19.7697**^{3a}	18.0979**^{1b}	-	-	-	-	

* Significant to 1%
** Significant to 5%

^{1} Linear deterministic trend — ^{2} No deterministic trend — ^{3} Quadratic deterministic trend
^{a} Intercept and trend — ^{b} Intercept, no trend — ^{c} No intercept, no trend

Notes: Pre-crisis period is 1/01/1993 – 30/05/1997, post-crisis period is 1/01/1998 – 1/01/2002. These periods have been chosen to exclude the structural breaks that occurred in the latter part of 1997. Typically lags 1-4 are used when specifying the test. Results indicating multiple cointegrating equations have been excluded.

Table 6-5: Gregory and Hansen Test for Cointegration

	1 January 1993 – 1 January 2002					
	AUSTRALIA		JAPAN		GERMANY	
	t	Date	t	Date	t	Date
INDONESIA	**-4.7789^**	1/23/1998	**-5.5645***	1/23/1998	**-4.7912^**	6/2/1998
MALAYSIA	**-7.2660***	7/10/1997	**-7.4601***	7/10/1997	**-7.3748***	7/10/1997
PHILIPPINES	**-6.1676***	8/9/1997	-2.7627	6/1/1995	-3.7065	9/10/1997
SINGAPORE	-4.3975	8/15/2000	-3.2971	5/10/1994	**-4.8444^**	10/31/1997
SOUTH KOREA	-3.9235	6/11/1997	**-4.9748^**	4/11/1997	-3.7734	4/11/1997
TAIWAN	-4.6754	1/2/2000	**-4.8008^**	11/25/1997	-3.2290	2/10/1997
THAILAND	-4.2205	7/25/1997	-3.8474	8/29/1997	-4.1421	10/9/1997

* Significant to 1%   ** Significant to 5%   ^ Significant to 10%

Notes: Critical values determined by Gregory and Hansen (1996) are (-5.45, -5.21, -4.99, -4.72) for (1%, 1.5%, 5%, 10%) respectively. Significant statistics are highlighted in bold.

is not so distinctive at the close of the century. If there is a yen bloc in post-crisis East Asia, then there is similar evidence for a "koala bloc", although it is perhaps more reflective of a broadening of Asian trading relationships beyond a reliance on Japan.

6.4 Conclusion

As global commerce becomes more widespread, and trading between geographically related economies intensifies, it is to be anticipated that the levels of cointegration between the currencies of such economies will increase. This study uses a variety of tests to show that there is evidence of integration between the Australian dollar, the German mark, the Japanese yen and the currencies of the East Asian region which has increased in the period subsequent to the 1997 currency crisis. The yen bloc, much anticipated by several researchers, seems to have lost some momentum during the 1990s.

The floating of several of the East Asian currencies subsequent to the crisis has affected the characteristics of the currencies. Structural breaks are evident in the data in the latter part of 1997 and were identified empirically using the Zivot and Andrews test for a unit root. General conclusions can be drawn from the results of statistical tests: the currencies of Indonesia, Malaysia and the Philippines exhibit long-run relationships with Australia over the duration of the study period. Indonesia, Malaysia, South Korea and Taiwan exhibit long-run relationships with Japan during this time, and Indonesia, Malaysia and Singapore exhibit a long-run relationships with Germany (the proxy for Europe) over the period. These results are supported by Granger causality testing, which demonstrates the existence of causal relationships between the developed economy currencies and those of East Asia. It is also interesting to note that the Granger causality test indicates that the relationships between the both Japan and Australian and the East Asian currencies work both ways – not only are Japan and Australia influencing the East Asian currencies, but several East Asian currencies may be influencing the Australian dollar and the Japanese yen. This is indicative of a deepening in regional economic integration, and may be a subject worth further study.

A notable result of this chapter is the observation that cointegrating relationships between the currencies of East Asian and developed economies have increased in the aftermath of the East Asian crisis, indicative of Asia's greater involvement in global trade and commerce. The weight of evidence does suggest that both Australia and Japan play important roles in the region, and there is some evidence of a currency bloc in Asia. However, the evidence presented here cannot discount the role of Germany, either, and suggests that while there is some move toward regional integration, there is a fair way to go before a decisive yen bloc, or koala bloc, can be said to exist in the East Asian region.

7 Cross-Hedging Effectiveness in Emerging Markets Experiencing Structural Change

Having identified significant regional currency relationships in Chapters 5 and 6, it is now possible to exploit these relationships by using these currencies in a cross-hedge. As discussed previously, a cross-hedge is a suitable alternative for a direct hedge that may be used in situations where there are no direct hedging products available. This chapter looks at the implementation of three different types of hedge ratio in cross-hedges, and analyses the effectiveness of the hedge ratio derivation methods for creating effective time-varying hedges during a period of currency stress, namely the 1997 East Asian currency crisis. Despite promising results from prior research, none of the hedge techniques exhibits outstanding performance during the study period. Performance varies between currency pairs, and while some general comparisons can be drawn between ratio hedges and full hedges, there is no consistent preference found for the error-correction model ratio over the Ederington minimum variance ratio, or vice versa.

7.1 Introduction

International investors are increasingly focussing on emerging market investments, which have been shown to provide profitable opportunities to diversify portfolio risk (Glen and Jorion, 1993) and often generate higher returns than may be available in more developed financial markets (Harvey, 1994). However, any foreign market investment leads to currency risk, and the risks in emerging markets can be high as they appear more prone to crisis. Effective currency hedging strategies provide additional risk-reduction benefits which can contribute to the performance of internationally diversified portfolios. However, most of these markets have relatively undeveloped derivatives markets, and for many emerging market currencies there are no exchange-traded derivative products available. Hence the only hedging solution available to foreign investors using exchange-traded currency futures is a cross-hedge based on another asset and/or contract. This provides an alternative to potentially costly over-the-counter solutions, such as forward contracts or currency swaps, and a cross-hedge may be ideal in circumstances when the transaction costs associated with an over-the counter solution prove to outweigh the financial benefits obtained from implementing an over-the-counter hedging strategy. Economically related currencies provide a superior hedge to economically unrelated currencies, and so an essential first step in the construction of a cross-hedge is to identify which currencies with liquid exchange-traded futures contracts are most closely correlated with the East Asian currencies being hedged. Aggarwal and Demaskey (1997) show that the Japanese yen futures contract provides a superior cross-hedge for Asian currencies to that of less related currencies such as the German mark and Swiss franc for the period of January 1983 to December 1992, while DeMaskey, Dellva and Heck (2003) show that the Japanese yen is an effective cross-hedge for mutual fund indices based on model in-sample goodness of fit (R^2). Other studies have demonstrated close relationships between the yen and the East Asian currencies, such as Gan (2000), Kwan (1994) and Zhou (1998), using OLS regressions and Johansen cointegration testing. However, no previous cross-hedging studies have considered alternatives such as the Australian dollar, which was shown in Chapter 6 to have a closer relationship with several East Asian currencies than either the yen or the German mark. This chapter initially identifies suitable currency futures contracts with which to form cross-hedges during the period examined using the Gregory and Hansen (1996) cointegration test, which adjusts for periods of structural change. Three hedges are then put in place: a full hedge, an Ederington (1979) minimum variance (EMV) ratio hedge, and a hedge using a ratio derived from an error-correction model (ECM) as per Ghosh (1996) in order to identify the most effective hedge ratio estimation technique for this period.

Cointegration testing is the fundamental first step when implementing an error-correction model hedge. The premise of cointegration is that there exists a long-run equilibrium relationship between the two series that may not be reflected in short-run dynamics. The error-correction model utilises this relationship to generate a more efficient hedge, and this has been demonstrated in work such as that by Kroner and Sultan (1993), Ghosh (1993b, 1996) and Lien (1996). If an error-correction model is not used when appropriate, other models of hedge ratio estimation may misspecify the ratio as they ignore prior-period information. During the period examined here, the East Asian currencies experienced structural changes that may cause cointegration testing methods such as the Johansen (1988) test to draw incorrect conclusions if they fail to adjust for structural breaks. As discussed previously, the Gregory and Hansen (1996) test for cointegration not only adjusts for structural breaks, but calculates the position of the breakpoint during the testing process, removing the potential for arbitrary period selection. This test is used to determine which futures contracts are most suitable to hedge the East Asian currencies being examined.

The 1997 East Asian currency crisis was a period of structural change in currency regimes coupled with a highly volatile adjustment period, when any investor would have been extremely concerned about the performance of an investment denominated in an East Asian currency. The selection of the most appropriate hedging strategy for such periods is of great interest to emerging market investors. This chapter looks at hedging performance during the 1997 East Asian currency crisis and examines which of the three hedging techniques performs best during this period of structural change. It finds that the error-correction model hedge ratio, which has been shown to be the most effective hedge in some studies of developed economy currencies (Ghosh, 1996) does not perform markedly better than the Ederington minimum variance hedge ratio under these conditions in the emerging market currencies examined. While log-likelihood ratios imply support for ECM ratio hedging, there is empirical evidence to suggest that the ECM ratios do not actually improve the average effectiveness of a hedge during periods of structural change. Measures of hedging performance such as the Sharpe and HBS measures do not find conclusively in favour of the ECM over the EMV ratio hedge, and show that there are marked differences in the performance of hedged portfolios across different currencies, despite these currencies sharing similarly dated structural breaks and regime changes, and despite these currencies belonging to regionally related economies. However, in each case a hedge improved the performance of the currency portfolios during the period immediately surrounding the structural break. While all hedges performed reasonably, the full hedge is the most effective and it may be preferable to use this simple technique when an investor anticipates structural change. Regardless of the technique used, it was better to be hedged than unhedged during the 1997 East Asian crisis.

7.2 Data

This chapter will again focus on a period of 2 years either side of the estimated breakpoints (found between July and December 1997).. The descriptive statistics for each currency during this time period can be found in Table 7-1.

This study uses daily (last settled trade of the day) data over a 60-day window to calculate the hedge ratio for the portfolio. A portfolio is then formed over a subsequent 30-day window, and performance statistics are calculated for that period. Each pair of windows will overlap with the next, thus giving results for any consecutive 30-day period throughout the duration of the study. These statistics are then averaged over the 750 portfolio windows[45]. Sub-period results are determined from a window of 120 days prior to and 60 days after the breakpoint identified by the Gregory and Hansen cointegration test. As a result, the actual dates comprising the sub-period vary between currency pairs. In each case, this results in 181 windows[46].

7.3 Method

The full (1:1) hedge results are compared against two alternate methods of calculating the hedge ratio, the Ederington minimum variance (EMV) hedge ratio and the ratio derived using the error-correction model (ECM). Ederington (1979) derived a hedge ratio that minimised the variance of a spot and futures portfolio from a simple OLS regression. The EMV hedge ratio β is estimated from the following equation:

$$R_{S,t} = \alpha + \beta R_{F,t} + \varepsilon_t \tag{46}$$

where $R_{S,t}$ is the return on the spot at time t,

and $R_{F,t}$ is the return on the futures at time t,

with error term ε_t

[45] Note that Malaysia has a reduced set of 743 portfolio windows.
[46] Note that due to the position of the breakpoint, the Malaysia/Australia sub-period hedge has a reduced set of 117 portfolio windows.

The EMV ratio was shown by Aggarwal and Demaskey (1997) to be superior to the full hedge for hedging performance when using the Sharpe measure. While the EMV ratio-derivation technique uses a simple regression formula, more complex methods have taken advantage of more specific series characterisation to find variance minimising ratios. A variety of methods, from ARCH and GARCH models to error-correction models can be used to characterise the relationship between spot and futures currency price series and ratios derived accordingly.

For the purposes of this chapter, an error-correction model will be used to calculate a hedge ratio as per Ghosh (1996) such that

$$\Delta R_{S,t} = \alpha + \beta \Delta R_{F,t} + \phi e_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta R_{F,t-i} + \sum_{j=1}^{n} \delta_j \Delta R_{S,t-j} + u_t \tag{47}$$

where n,m are values that generate white noise u_t and are chosen based on the values (between 1 to 6) that generate the lowest Akaike information criteria (Ghosh, 1996). The ECM ratio has the advantage of adjusting for autocorrelation in the series, as is often apparent in currency series (see for example Liu and He, 1991). Ghosh concluded that this technique performed more effectively than the EMV ratio hedge when used to cross-hedge a number of developed economy currencies.

The performance of a hedge can be assessed using a variety of measures, as discussed in section 2.4. This chapter will use the R^2 measure for in-sample performance assessment, and both the Sharpe (1994) measure and the Howard and D'Antonio (1987) HBS measure for out-of-sample performance assessment. As discussed previously, the Sharpe measure provides an assessment of the out-of-sample risk-return characteristics

Table 7-1 : Descriptive Statistics[47]

Currency	Mean (sub-period)	Maximum (sub-period)	Minimum (sub-period)	Skewness (sub-period)	Kurtosis (sub-period)	Variance (sub-period)
INDONESIA	0.1177	31.5778	-23.5743	1.6252	28.8531	12.4571
	(0.6418)	(31.5778)	(-23.5743)	(0.8800)	(11.1487)	(35.8619)
MALAYSIA	0.0431	11.8716	-11.4562	0.0464	34.9951	1.3424
	(0.1761)	(7.6281)	(-7.9547)	(-0.0973)	(7.2226)	(3.1749)
PHILIPPINES	0.0413	8.7865	-4.4696	2.6108	25.2799	0.9290
	(0.1650)	(8.7865)	(-4.4696)	(1.5040)	(9.2147)	(2.7288)
SINGAPORE	0.0187	3.3961	-3.9690	-0.7149	13.3416	0.3001
	(0.0579)	(3.3961)	(-3.9690)	(-0.5029)	(7.0102)	(0.6912)
SOUTH KOREA	0.0473	13.6104	-20.1655	-1.0118	47.9051	2.5522
	(0.1539)	(13.6104)	(-20.1655)	(-0.7789)	(17.4306)	(7.7345)
TAIWAN	0.0176	3.3931	-3.3418	1.6885	31.1601	0.1630
	(0.0745)	(3.3931)	(-3.3418)	(1.1291)	(13.7401)	(0.3962)
THAILAND	0.0418	17.0751	-6.2039	2.5713	47.4442	1.5042
	(0.1890)	(17.0751)	(-6.2039)	(1.4881)	(17.2293)	(4.4914)
AUSTRALIA	0.0140	2.5963	-5.1682	-1.0028	10.1237	0.4545
	(0.0714)	(2.5963)	(-3.6446)	(-0.6241)	(5.8414)	(0.6257)
GERMANY	0.0257	1.8332	-2.1792	-0.2034	4.2733	0.2965
	(0.0157)	(1.5569)	(-1.5530)	(-0.1432)	(3.4581)	(0.3236)
JAPAN	0.0109	3.9549	-7.6773	-1.2288	13.5575	0.6880
	(0.0624)	(2.6936)	(-4.7855)	(-1.0693)	(7.5388)	(0.6913)

Notes: Full period statistics are from 1 January 1996 – 30 July 1999. Indicative sub-period statistics are from 2 June 1997 – 30 June 1998. Actual sub-period results will vary depending on the location of the breakpoint.

[47] Results are for the return series $R_t = \ln(C_t/C_{t-1}) * 100$, where C = currency. All currencies are denominated in US dollars.

of the hedge, while the HBS measure provides a simple assessment of the portfolio performance relative to the unhedged portfolio.

The return in a situation where the company is long the currency and short the futures contract is:

$$R_P = R_S - \beta R_F \tag{48}$$

where R_P is the return of the hedged portfolio,

R_S is the return on the spot,

and R_F is the return on futures.

The resulting Sharpe ratio will be calculated for each strategy to measure the effectiveness of the hedge, such that

$$SR_P = \frac{R_P - R_f}{\sigma_P} \tag{49}$$

where σ_P is the standard deviation of the portfolio,

and R_f is the risk-free rate of return (US 90 day T-Bills).

This results in an index that generates a higher value as the hedge increases in efficiency (i.e. exhibits an improvement in the risk-return performance of the portfolio). The Sharpe ratio of the hedged portfolio is compared with that of the unhedged portfolio (i.e. the spot), thus analysing the relative performance of each to determine the preferable portfolio to hold. Additionally, the Howard and D'Antonio (1987) modified Sharpe measure is also calculated, and is given as:

$$HBS = \frac{R_f + SR_P\sigma_S - R_S}{\sigma_S}$$

$$(50)$$

where SR_P is the Sharpe ratio of the hedged portfolio,

and σ_S is the standard deviation of the spot portfolio.

A *HBS* ratio of zero indicates no performance difference per unit of risk between the hedged and spot portfolios. A negative *HBS* ratio indicates that the spot portfolio generates a higher return than the hedged portfolio per unit of risk, and a positive value indicates that the hedged portfolio generates a higher return per unit of risk. For an investor to prefer the hedged portfolio, the *HBS* ratio should be positive.

Cointegration testing will take place as outlined in section 6.2.1. The Gregory and Hansen test is used here to define cointegrating relationships between East Asian currencies and Japanese, German and Australian currency futures, and to confirm the existence of structural breaks. Those pairs demonstrating the strongest cointegrating relationships are used to form a cross-hedge.

7.4 Results

The IMF has identified changes in the nature of East Asian currency regimes during the crisis based on changes in official Government policy (Table 4-2). The results of the Gregory and Hansen test (Table 7-2) confirm this, having successfully identified breakpoints in the East Asian currencies during the crisis period from statistical indicators. Breakpoints range from the 23rd of June 1997 in the case of Thailand, to the 27th of July 1998 for the Malaysia/Australia currency pair. Most breakpoints are identified as having occurred in one of two main periods: between June and July 1997, and between December 1997 and February 1998. The crisis period is marked by significant increases in variance (Table 7-1) and, with the exception of Malaysia, extreme returns (with both the maximum and minimum returns for all other East Asian currencies falling within the crisis sub-period).

An effective cross-hedging instrument is one that is strongly related to the asset being hedged, and correlation statistics are an indicator of this relationship. Correlation statistics (Table 7-3) demonstrate a close relationship between the Australian dollar futures contracts and the East Asian currencies, with statistics ranging from 0.83 (South Korea and Thailand) to 0.96 (Taiwan). The strength of each East Asian currency's correlation with the Australian dollar futures contracts (and by implication the Australian dollar, since the futures contracts are highly correlated with the spot) is significantly greater than that of the alternate hedging instruments, the yen and mark futures contracts. The strongest correlation result for the German mark futures is with the Singapore dollar, at 0.75, and Taiwan has the strongest level of correlation with the Japanese yen futures at 0.75. If constructing full or minimum variance ratio hedges, these results would lead to the use of the Australian dollar futures contract as the preferred hedging instrument for each East Asian currency examined, and to expect that the alternative hedges would underperform those using the Australian dollar.

However, when implementing the ECM ratio hedge it is important to consider the results of cointegration testing. As discussed previously, the Gregory and Hansen test is particularly suitable for determining cointegrating relationships over the crisis period as it adjusts for the presence of structural breaks. The Gregory and Hansen test finds evidence of cointegration over the full testing period of January 1996 to August 1999

Table 7-2: Gregory and Hansen Test for Cointegration

	1 January 1996 – 30 July 1999					
	AUSTRALIAN FUTURES		GERMAN FUTURES		JAPANESE FUTURES	
	t	Date	t	Date	t	Date
INDONESIA	**-5.1690^**	1/12/1998	**-4.9434^**	2/09/1998	**-4.9450^**	1/21/1998
MALAYSIA	**-5.5381****	7/27/1998	**-4.9953***	2/03/1998	-3.6451	1/21/1998
PHILIPPINES	-4.1910	12/02/1997	-4.4602	7/08/1997	-3.7965	7/08/1997
SINGAPORE	-3.7987	8/12/1997	-3.5980	8/12/1997	-3.4326	8/26/1997
SOUTH KOREA	**-5.0034***	12/10/1997	-3.9214	12/11/1997	-3.7043	12/10/1997
TAIWAN	-4.5087	11/06/1997	-3.7589	2/06/1998	-3.4227	10/21/1997
THAILAND	**-4.9855^**	6/23/1997	-4.3064	6/23/1997	-4.4765	6/23/1997

** Significant to 1%
* Significant to 5%
^ Significant to 10%

Critical values determined by Gregory and Hansen (1996) are (-5.45, -5.21, -4.99, -4.72) for (1%, 1.5%, 5%, 10%) respectively.

Notes: Cointegration testing was performed using the Gregory and Hansen (1996) test, which accommodates structural breaks in the time series. The results indicate that Australian dollar futures would be the most appropriate contract with which to cross-hedge the South Korean won, the Thai baht, Malaysian ringgit and Indonesian Rupiah when using an error-correction model. Japanese yen futures or German mark futures may also be used to cross-hedge the Indonesian Rupiah, and German mark futures could be used to cross-hedge the Malaysian ringgit. There is no evidence of cointegration between any of the futures contracts and the Philippines peso, Singapore dollar, or Taiwan dollar.

Table 7-3 : Correlation Statistics

CURRENCY	1 January 1996 – 30 July 1999		
	AUSTRALIAN FUTURES	**GERMAN FUTURES**	**JAPANESE FUTURES**
AUSTRALIA	0.9996	0.6306	0.6976
GERMANY	0.6200	0.9997	0.6975
JAPAN	0.6927	0.6981	0.9989
INDONESIA	**0.9101**	0.5932	0.7478
MALAYSIA	**0.9390**	0.7015	0.7036
PHILIPPINES	**0.9546**	0.6849	0.7158
SINGAPORE	**0.9392**	0.7452	0.6813
SOUTH KOREA	**0.8304**	0.6702	0.7238
TAIWAN	**0.9612**	0.6921	0.7516
THAILAND	**0.8351**	0.7395	0.7318

Notes: Correlation statistics indicate that the East Asian currencies are most closely correlated with the Australian dollar futures contract during the crisis period. If hedging currency selection is based on correlation results, the Australian dollar futures contract would be selected as the cross-hedging instrument in all instances.

between Australian dollar futures and the currencies of Indonesia, Malaysia, South Korea and Thailand, between German mark futures and the currencies of Indonesia and Malaysia, and between Japanese yen futures and the Indonesian rupiah. The existence of these relationships, particularly the greater number of currencies that are cointegrated with Australian dollar futures compared to those cointegrated with Japanese yen futures, confirms the findings of Chapter 6 and reinforces the conclusions drawn from the correlation statistics. Using the results of the Gregory and Hansen tests, cross-hedges are formed between the Australian dollar futures and the Indonesian rupiah, the Malaysian ringgit, the South Korean won and the Thai baht. German mark futures are used to cross-hedge the Indonesian rupiah and the Malaysian ringgit, while Japanese yen futures are used to cross-hedge the Indonesian rupiah.

Table 7-4 and Table 7-5 contain the average results for the portfolios formed over the study period. As per Aggarwal and Demaskey (1997), the Sharpe measure is used to assess the performance of the hedge, with a superior hedge generating a higher Sharpe measure. Average Sharpe measures for both the hedged and spot portfolios are generated, and the results can be compared to give an indication of the success of a hedge in contrast to an unhedged (spot) position. None of the spot portfolios studied had a positive Sharpe ratio over either the full period or sub-period, indicating that the average spot portfolio in both timeframes underperformed the risk-free (T-bill) rate. The hedged portfolios were also generally negative in both periods, with the exception of the Malaysia/Australia hedge during the sub-period, and the full period Indonesia/German mark and Indonesia/Japanese yen full-hedges. In most cases the hedged portfolios generated Sharpe ratios that were closer to zero than those of the spot portfolios, indicating that while the portfolio did not outperform the risk free rate, it did perform

Table 7-4: Average Performance Measurements for Australian Dollar Hedged Portfolios

AUSTRALIAN DOLLAR FUTURES	Hedge Ratio		Sharpe (Hedge)		Sharpe (Unhedged)		Hedge vs. Unhedged Return[48] ($*10^{-3}$)		Hedge Outperforms Unhedged (%)		HBS	
INDONESIA	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period
Full Hedge	1	1	-0.2383	-2.1100	-2.7544	-3.1561	0.0177	0.0655	59.06	72.93	2.5161	1.0461
EMV Hedge	0.6522	1.6849	-2.2439	-1.7692	-2.7544	-3.1561	0.0223	0.0774	58.82	86.74	0.5105	1.3869
ECM Hedge	0.4900	0.7568	-2.3254	-2.5154	-2.7544	-3.1561	0.0152	0.0526	53.51	65.75	0.4291	0.6407
MALAYSIA												
Full Hedge	1	1	-0.9716	0.3128	-2.3995	-1.5007	0.0161	0.0336	72.19	90.60	1.4279	1.8135
EMV Hedge	0.3718	1.1549	-1.4296	0.9528	-2.3995	-1.5007	0.0108	0.0425	66.39	89.74	0.9699	2.4535
ECM Hedge	0.3046	0.9013	-1.4343	0.4853	-2.3995	-1.5007	0.0103	0.0351	71.69	90.60	0.9652	1.9860
SOUTH KOREA												
Full Hedge	1	1	-0.1660	-0.7378	-1.5318	-2.2841	0.0038	0.0004	59.80	69.61	1.3658	1.5462
EMV Hedge	0.1431	0.1843	-1.2832	-1.8775	-1.5318	-2.2841	0.0013	-0.0098	58.32	75.69	0.2486	0.4065
ECM Hedge	0.1349	0.1803	-1.1806	-1.9097	-1.5318	-2.2841	0.0011	-0.0107	56.72	71.82	0.3512	0.3744
THAILAND												
Full Hedge	1	1	-0.2371	-1.8857	-2.2400	-5.6415	0.0058	0.0071	55.61	59.12	2.0029	3.7558
EMV Hedge	0.3180	0.1924	-2.4137	-5.2296	-2.2400	-5.6415	0.0033	-0.0007	57.58	56.35	-0.1738	0.4119
ECM Hedge	0.3463	0.2824	-2.3072	-5.2145	-2.2400	-5.6415	0.0041	-0.0018	56.23	50.83	-0.0672	0.4269

* Hedge is preferred

Notes: Hedged vs. Unhedged Return is defined as $\frac{1}{n}\sum_{i=1}^{n}(R_P - R_S)$. Hedged Outperforms Unhedged (%) gives the percentage of times that the hedged portfolio return (RP) is greater than the spot portfolio return (RS). Hedge estimation period is 60 trading days, while hedge duration is 30 trading days. Sub-period results are for the 181 day period surrounding the breakpoint (120 days before, 60 days after), resulting in a maximum of 181 hedge windows, with the exception of the Malaysia/Australia hedge, which has a maximum of 117 due to the location of the breakpoint and the fixed currency.

[48] Note that the return is relative to the unhedged portfolio only. It does not incorporate the risk-free (T-bill) rate.

better than the spot portfolio. In these cases, it was preferable to hedge, as a spot portfolio would have resulted in a greater loss on average, and this was reflected in positive HBS measures. This was particularly evident in the sub-period, which surrounded the breakpoint of each currency pair. Some German mark hedges performed poorly in contrast to the spot portfolio, but all other sub-period hedges exhibited improved performance in contrast with that of the spot portfolio. This was particularly evident for the ratio hedges, with performance improvements seen consistently between the full and sub-periods. However, the Sharpe performance of the ratio hedges was often poorer than that of the full hedges, indicating that the full hedge was generally the most successful hedging technique. Both the full and sub-period hedges demonstrate this effect.

The *Hedged vs. Unhedged Return* column contains the average of the difference between the return on the hedged portfolio and the return on the spot portfolio, and hence gives an indication of the profitability of the hedges. A positive number here indicates that the hedged portfolio generated a greater return than the spot portfolio, while a negative return indicates that the spot portfolio was more profitable than the hedged portfolio. The average hedged portfolio typically generated a positive return and was therefore more profitable than the spot, with the exceptions of some Korean won and Thai baht sub-period ratio hedges. While the return on the portfolio may have been less than the risk-free rate, an investor would generally have received a greater return had they implemented a hedge, as opposed to leaving the portfolio unhedged. The hedged portfolios generally outperform the spot portfolios, and this is particularly evident for the full period results. The only exceptions were Thai and Korean ratio

Table 7-5: Average Performance Measurements for Japanese Yen and German Mark Hedged Portfolios

GERMAN MARK FUTURES	Hedge Ratio		Sharpe (Hedge)		Sharpe (Unhedged)		Hedge vs. Unhedged Return[49] ($*10^{-3}$)		Hedge Outperforms Unhedged (%)		HBS	
INDONESIA	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period
Full Hedge	1	1	0.6084	-3.2514	-2.7544	-3.1955	0.0184	0.0372	61.90	49.17	3.3628	-0.0559
EMV Hedge	0.4860	0.6271	-2.6361	-3.2053	-2.7544	-3.1955	0.0062	0.0347	52.90	55.80	0.1184	-0.0098
ECM Hedge	0.9521	2.4057	-2.8075	-3.7450	-2.7544	-3.1955	0.0003	0.0088	46.12	48.07	-0.0531	-0.5495
MALAYSIA												
Full Hedge	1	1	-0.4498	-3.2245	-2.3995	-3.3839	0.0099	0.0018	62.91	49.72	1.9497	0.1594
EMV Hedge	0.1545	0.1598	-1.6968	-2.9927	-2.3995	-3.3839	0.0037	0.0073	65.73	57.46	0.7027	0.3912
ECM Hedge	0.1592	0.1651	-1.6216	-2.9603	-2.3995	-3.3839	0.0043	0.0079	74.01	74.59	0.7779	0.4236

JAPANESE YEN FUTURES	Hedge Ratio		Sharpe (Hedge)		Sharpe (Unhedged)		Hedge vs. Unhedged Return[47] ($*10^{-3}$)		Hedge Outperforms Unhedged (%)		HBS	
INDONESIA	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period	Full Period	Sub-Period
Full Hedge	1	1	0.3211	-2.2064	-2.7544	-3.1469	0.0156	0.0569	63.13	72.38	3.0755	0.9405
EMV Hedge	0.4146	0.9124	-2.3549	-2.2549	-2.7544	-3.1469	0.0214	0.0663	58.45	77.90	0.3995	0.8920
ECM Hedge	0.4129	0.9136	-2.2418	-2.2853	-2.7544	-3.1469	0.0217	0.0677	54.01	65.19	0.5126	0.8616

* Hedge is preferred

Notes: Hedged vs. Unhedged Return is defined as $\frac{1}{n}\sum_{i=1}^{n}\left(R_P - R_S\right)$. Hedged Outperforms Unhedged (%) gives the percentage of times that the hedged portfolio return (R_P) is greater than the spot portfolio return (R_S). Hedge estimation period is 60 trading days, while hedge duration is 30 trading days. Sub-period results are for the 181 day period surrounding the breakpoint (120 days before, 60 days after), resulting in a maximum of 181 hedge windows, with the exception of the Malaysia/Australia hedge, which has a maximum of 117 due to the location of the breakpoint and the fixed currency.

[49] Note that the return is relative to the unhedged portfolio only. It does not incorporate the risk-free (T-bill) rate.

hedges during the sub-period, which were generally not as profitable as the spot positions.

Overall, the mostly positive HBS measures reinforce the general preference to hedge. With the exception of the German mark hedges, the HBS measure for the ratio hedges generally improved during the sub-period, often quite markedly, and full hedges were universally strongly positive over the full period. The full hedge is generally shown to be preferable to the EMV and ECM ratio hedges from a portfolio theory perspective, generating greater Sharpe ratios than those of the EMV and ECM ratio hedges and hence generating higher positive HBS measures. The superior risk-return properties of the full hedge are evident. However, ratio-based hedges often require fewer futures contracts than a full hedge does. Estimated hedge ratios (shown in the first columns of Table 7-4 and Table 7-5) are as low as 0.13 – 0.14 in the case of the South Korea/Australia hedges, although occasionally the sub-period hedges result in ratios greater than 1. Cost savings may be possible using a hedge ratio, and while the ratios generally underperform the full hedge, the potential cost savings should be taken into account as in many cases the performance difference may not outweigh transaction costs.

Also interesting to note is that the average ECM hedge ratio is not consistently smaller than the average EMV hedge ratio. Ghosh (1997) found that the ECM hedge ratio tended to be smaller than the EMV hedge ratio. However, the results here find that the average EMV hedge ratio is often smaller than the ECM hedge ratio, in which case the EMV ratio would provide transaction costs savings compared to the ECM ratio, or they are equivalent. The difference between the results found here and those of Ghosh are likely to be the result of period specific behaviour in that study, while in this the results are shown for multiple windows over the time period. Additionally, Ghosh estimates the ratios over a much longer hedging period (400 observations, while only 60 are used here), and hence the results may be subject to misspecification due to the time-varying nature of hedge ratios. In this implementation, the use of short-term, time-varying hedges do not result in a strong out-of-sample performance preference for the ECM ratio hedge.

Table 7-6 compares the EMV and ECM ratios using a range of performance statistics. Here, R^2 statistics are used to evaluate the in-sample effectiveness of the hedge ratio. ECM hedge ratios generate larger average values of R^2, indicating that ECM hedge ratios provide a better model fit than EMV ratios. However, out-of-sample statistics generally favour the performance of EMV ratio hedges, and, more often than not, higher HBS values indicate that EMV ratio hedges outperform ECM ratio hedges. Only two hedges, those of Malaysia/Germany and South Korea/Australia, consistently generate higher HBS measures for error-correction model ratio hedges than for Ederington minimum variance ratio hedges. In most other cases, Ederington minimum variance ratios result in larger HBS ratios, and this is particularly evident during the crisis sub-period. The superior error-correction model performance seen in-sample from the R^2 statistics is not being translated into superior out-of-sample performance. For example, the (in-sample) R^2 statistics for the Indonesia hedges indicate that the ECM ratio significantly outperforms the EMV ratio during the sub-period in terms of model fit, while the HBS ratios derived from the (out-of-sample) hedge indicate better performance from the EMV ratio hedges. It may be that an analysis of hedging success based on in-sample statistics such as R^2 is not sufficient to indicate the success of a

Table 7-6: Selected Statistics for EMV and ECM Ratios.

		EMV R^2	ECM R^2	Hedge Ratio (EMV) Greater Than Hedge Ratio (ECM) (%)	HBS (EMV) Greater Than HBS (ECM) (%)
INDONESIA/AUSTRALIA	**Full Period**	0.03	0.21	49.45%	50.55%
	Sub-Period	0.07	0.27	67.40%	71.82%
INDONESIA/GERMANY	**Full Period**	0.02	0.22	40.44%	58.57%
	Sub-Period	0.02	0.29	27.62%	74.03%
INDONESIA/JAPAN	**Full Period**	0.02	0.22	47.60%	52.65%
	Sub-Period	0.02	0.27	54.70%	69.06%
MALAYSIA/AUSTRALIA	**Full Period**	0.07	0.30	57.45%	52.15%
	Sub-Period	0.17	0.37	59.83%	63.25%
MALAYSIA/GERMANY	**Full Period**	0.04	0.28	50.83%	43.71%
	Sub-Period	0.01	0.31	54.14%	39.78%
SOUTH KOREA/AUSTRALIA	**Full Period**	0.01	0.22	54.99%	42.17%
	Sub-Period	0.01	0.22	56.35%	45.30%
THAILAND/ AUSTRALIA	**Full Period**	0.07	0.26	47.97%	49.69%
	Sub-Period	0.01	0.36	46.41%	60.77%

Notes: This table contains selected statistics for both the full 3-year period, and the period immediately incorporating the structural breaks observed during the 1997 East Asian crisis. Hedge ratios during the sub-period generally resulted in higher R^2 values for those currencies hedged against the Australian dollar, indicating a better hedge ratio fit. This was particularly evident for EMV ratio hedges. With a few exceptions, EMV ratio hedges generally resulted in higher HBS measures than ECM ratio hedges. These results contrast with the average R^2 values – a preference for the ECM ratio is evident, which is not borne out by out-of-sample hedge performance analysis. The ratios for the ECM ratio hedges are not considerably smaller than those of EMV ratio hedges, with mixed results seen throughout the hedging periods. Few hedges generated a substantial number of ECM hedge ratios that were smaller than the EMV ratios.

practical hedging strategy. In-sample efficiencies are not translated here into out-of-sample performance. Further, strong HBS ratios for EMV ratio hedges are evident during the sub-period surrounding breakpoints, where long-run trends are being disrupted by short-term events.

There is no clear evidence here to support a preference for one method of selecting a ratio over the other, with hedge performance varying depending on the currency pair. Hedge ratio size provides little additional guidance – while the EMV ratio is generally larger than the ECM ratio, this is not universally the case and so it cannot be definitively said that efficiencies in transaction cost savings accrue to one technique more than the other. Further, despite prior evidence as to the effectiveness of EMV ratio cross-hedges with emerging market currencies (Aggarwal and Demaskey, 1997), there is no clear evidence here to support the implementation of either ratio hedge in preference to a full hedge based on risk-adjusted performance. The only advantage of a ratio hedge is that often very small ratios are observed, and in these cases a saving in transaction costs may result in a more profitable outcome for the hedger than if a full hedge is used. However, these are matters for the individual, and will change depending on their circumstances.

7.5 Conclusion

The practice of cross-hedging has been shown here to generally benefit an emerging market currency portfolio during periods of structural change when the alternative is an unhedged (spot) portfolio. In the majority of instances studied, the two ratio-based hedges were not as effective as full hedges, and currency pairs tended to perform better with a full hedge during the period immediately surrounding a structural break. These results indicate that the traditional full hedge is possibly a more practical hedge to implement in an emerging market economy, particularly if structural change is anticipated. However, in some instances the average hedge ratio estimated using the Ederington minimum variance and error-correction models is significantly less than 1. In these circumstances, it may be optimal for the hedger to use a ratio hedge in order to take advantage of any transaction cost savings. As always, the individual circumstances of the hedger regarding transaction costs must be taken into account before a final decision regarding profitability can be made.

This chapter also finds that the minimum variance hedge ratio generally performs as well, if not better than the error-correction model hedge ratio, and the implementation of the ECM ratio provides no large or consistent improvement in terms of performance, ratio size, or profitability. While studies such as Ghosh (1996) find a stronger preference for the ECM hedge ratio when observing the log-likelihood and R^2 statistics, the use of out-of-sample hedging performance measures such as the HBS and Sharpe measures here indicate that an error-correction model ratio is not necessarily preferable to the minimum variance ratio when cross-hedges are executed. This concurs with the findings of Chen, Lee and Shrestha (2003) that there is not one hedge ratio estimation technique that is overwhelmingly superior to alternatives.

This chapter has used a moving window approach to examine the effectiveness of 30-day hedges during a period incorporating the 1997 East Asian currency crisis to determine whether a currency cross-hedging strategy delivers tangible benefits to investors with East Asian (and hence emerging market) currency exposures. The full hedge generally appears to be the more effective technique when hedging an investment in a currency that is undergoing structural change. As a result, the best general hedging advice may be to "keep it simple": a full hedge is an effective and often profitable technique to use with structurally adjusting East Asian currencies.

8 Lower Partial Moment Cross-Hedges

An alternative to a minimum variance hedge ratio is one that seeks to minimise a specific type of risk. The lower partial moment hedge ratio aims to minimise downside risk, and is based on an alternative definition of risk as a shortfall from some target return. While there are now a number of studies investigating the lower partial moment hedge ratio, none have sought to apply this to a cross-hedge. Further, previous studies have concentrated on developed economies. This chapter examines the effectiveness of cross-hedging using lower partial moment ratios for East Asian currencies and compares them to the traditional minimum variance model ratio hedge of Ederington (1979). These hedges are examined over a three year period incorporating the 1997 East Asian currency crisis, to see if the lower partial moment ratio improved hedging performance compared to that of the minimum variance ratio hedge. The findings are very positive, although they are mitigated by often higher hedge ratios than would otherwise be the case. As such, the lower partial moment may provide hedging benefits to investors, but they must regard their individual circumstances carefully to ensure that the benefits are not offset by increased transaction costs.

8.1 Introduction

The portfolio theory of hedging regards the motivation to hedge as having two aims: to minimise risk, and to maximise return. Variance is often held out as the measure of risk most associated with hedging strategy, and variance reduction is a major objective when estimating a hedge ratio. The Ederington (1979) minimum variance ratio seeks, as the name suggests, to minimise portfolio variance so that the value of the portfolio remains as constant as possible. However, variance has an upside as well as a downside, and the pursuit of variance minimisation objective may be at the expense of return maximisation. Minimum variance hedge ratio hedging typically attempts to keep the outcome at a defined level, where both upside and downside risk are treated as equally undesirable. This would be a suitable ratio if an investor were infinitely risk-averse, but in reality many investors are happy to deviate from a defined value if the result is a profit, although few investors are happy if the variance results in a loss. It is often argued that an investor wishes to minimise the risk of losses, or downside risk, while maximising profits, or upside risk.

Building on this idea, Fishburn (1977) proposed that investors may be particularly averse to downside risk but may be perfectly willing to accept upside risk, and hence may wish to find a hedging strategy that minimises portfolio losses without also removing the potential for gains. This can be done utilising the lower partial moment theory. The lower partial moment is the left-hand tail of the return distribution, and as such encompasses only the lowest returns in the distribution. Bawa (1978) showed that the lower partial moment is consistent with the expected utility of a wealth maximising investor who wishes to minimise losses while maximising returns. By generating a hedge ratio from the lower partial moment, it is possible to construct a hedge that limits downside risk to a level determined by the investor's appetite for risk while maintaining the potential to accrue profits (Eftekhari, 1998, Lien and Tse, 2000).

The lower partial moment hedge ratio derivation techniques of Eftekhari and Lien and Tse are extensions of this work, allowing a hedge ratio to be derived based on the lower partial moment of the return distribution function that may be adjusted for the individual investors risk aversion and target portfolio return. The secondary benefit of the lower partial moment is that there are no assumptions made about the return distribution: the ratio is generated iteratively from a sample of existing returns, and as such works with the observed return distribution. It does not make an assumption that the return distribution is normal, and thus it refrains from assumptions of normality that may not be appropriate to currency markets.

Lower partial moment hedging[50], therefore, is a method which may be of interest to investors with foreign currency holdings who wish to hedge their portfolio against the possibility of negative currency movements, but are happy to see returns should exchange rates move in their favour.

8.2 Data

The data used in this chapter is generally identical to that of Chapter 7. This chapter does not use the German mark as a contrasting currency, focusing instead on the yen and the Australian dollar, as they were found in Chapter 7 to provide the most beneficial hedges for the East Asian currencies. A full discussion of the data can be found in section 7.2. Indonesia was eliminated from this study as the LPM method results in estimated hedge ratios greater than *abs(2.5)* for a number of windows. To accurately estimate these ratios, a wider estimation range needs to be examined, which significantly increases the execution time of the estimation code. As a result, a full investigation of the results for Indonesia (including the cause of the very large hedge ratio estimates) is left for future research.

[50] Lower partial moment hedging is also sometimes referred to as generalised semi-variance hedging, as per Chen, Lee and Shrestha (2003)

8.3 Method

The lower partial moment (LPM) hedge ratio is designed to minimise downside risk while maximising upside potential, in contrast to a minimum variance hedge ratio that is designed to minimise portfolio variance, this containing both upside and downside. The salient question, therefore, is whether the LPM hedge ratio will generate greater risk-return tradeoffs than the Ederington minimum variance (EMV) hedge ratio[51]. The EMV ratio can be used as a representative minimum variance hedge ratio in this situation to contrast the performance of the LPM ratio, as is done similarly by Eftekhari (1998), Lien and Tse (2000) and Demirer and Lien (2003).

The lower partial moment is essentially the probability that a return will fall below a target rate, and is discussed in detail in section 2.1.1. To briefly recap, Lien and Tse (2000) show that the LPM hedge ratio β_{LPM} can be derived from the empirical distribution function:

$$LPM(R_\tau, n, R_p) = \sum_{r_i < c} \left(\frac{1}{N}\right)(R_\tau - R_{p,i})^n \tag{51}$$

where R_p is the return on the hedged portfolio with hedge ratio β_{LPM},

τ is the target return for the portfolio,

and N is the maximum number of portfolios formed to calculate the ratio.

The ratio is derived from an iterative process, whereby different values of β_{LPM} are tested in a range from -1.5 to 1.5 in appropriate increments (Eftekhari uses 0.001) and the value of β_{LPM} that generates the smallest lower partial moment is chosen as the hedge ratio. Lien and Tse show that this relatively simple method generates results

[51] See section 2.1.1 for a detailed discussion of the Ederington minimum variance ratio

consistent with the alternative kernel estimation method and it will be used in this study to generate LPM ratios.

As there is no published work investigating lower partial moment cross-hedging, there are myriad avenues for investigation. It is not possible to cover all the areas of interest uncovered in this thesis, so this chapter is purposely limited in scope. During the data analysis process, a number of interesting features were noted that could not be investigated further, and several of these are outlined below.

Lower partial moment ratios are estimated for direct hedges of the Japanese yen and Australian dollar, while ratios for cross-hedges are estimated for East Asian currencies. As processing power has improved since Eftekhari, increments of 0.0001 are used for a range of -2.5 to 2.5, as it was found during the ratio generation process that the LPM hedge ratio estimated for cross-hedges was often larger than those estimated for direct hedges. Further investigation into the reasons for these large hedge ratios is left for future study.

The lower partial moment risk-aversion parameter, n, is set to 2 for the purposes of this chapter as the focus is on the performance of the ratio in comparison to those estimated using minimum variance techniques. By setting $n = 2$, the lower partial moment is the moment of variance, and so is most equivalent to the minimum-variance ratio. Other moments may also be used, as was done by Lien and Tse (2000). Both Eftekhari and Lien and Tse show that the optimal hedge ratio to minimise downside risk increases with the investor's sensitivity to downside risk. In other words, as the investor becomes more loss-averse, the optimal hedge ratio increases in absolute magnitude. This may result in quite different ratios being implemented using the LPM technique than those of the MVR technique. As yet, no studies of the LPM ratio consider cross-hedging, and the results derived here will be contrasted with those of the direct hedge to see if such assumptions are applicable in this context. The exploration of moments other than 2 will be left for future study.

As the LPM ratio is not based on a pure variance-minimisation framework, measures of hedging effectiveness based on variance minimisation are inappropriate. Statistics such as the Sharpe (1964) measure are inappropriate here as they treat payoffs as symmetric. Instead, the performance of the hedge will be measured by the number of below-target returns generated by the hedge, and the overall profitability of the hedge. Alternative methods of performance, such as the ratio constructed by Demirer and Lien (2003) from the minimum lower partial moment of the hedged and unhedged portfolios, will be left for future study.

8.4 Results

This chapter uses the same data set as that of Chapter 7, and a full discussion of the results of correlation tests (Table 7-3) and cointegration tests (Table 7-2) can be found there. This chapter not only compares the performance of different hedge ratio estimation techniques and their performance in cross-hedges, but also compares the results of direct hedges with those of cross-hedges. As no prior published literature on cross-hedges is available, it is necessary to establish a "standard behaviour", with which comparisons can be made. The results of direct hedges for the Australian dollar and

Table 8-1: Performance Results for Portfolios with Australian Dollar Futures, n = 2

	LPM = -0.5	LPM = 0	EMV	Spot	LPM = 0.5
AUSTRALIA					
Mean Portfolio Return	0.0025	0.0006	0.0005	0.0076	0.0006
(std. dev.)	(0.0032)	(0.0026)	(0.0026)	(0.0065)	(0.0027)
Portfolio Return < 0 (%)	35.21	39.05	41.23	37.39	37.00
$R_{LPM} > R_{EMV}$ (%)	65.17	58.26			53.39
MALAYSIA/AUSTRALIA					
Mean Portfolio Return	0.0092	0.0095	0.0094	0.0154	0.0100
(std. dev.)	(0.0086)	(0.0080)	(0.0079)	(0.0081)	(0.0080)
Portfolio Return < 0 (%)	44.81	43.02	43.41	29.45	44.43
$R_{LPM} > R_{EMV}$ (%)	54.16	46.99			51.34
PHILIPPINES/AUSTRALIA					
Mean Portfolio Return	0.0138	0.0132	0.0128	0.0141	0.0130
(std. dev.)	(0.0082)	(0.0076)	(0.0075)	(0.0075)	(0.0077)
Portfolio Return < 0 (%)	39.56	34.06	32.65	30.47	39.18
$R_{LPM} > R_{EMV}$ (%)	55.83	52.24			54.67
SINGAPORE/AUSTRALIA					
Mean Portfolio Return	0.0052	0.0051	0.0047	0.0074	0.0052
(std. dev.)	(0.0050)	(0.0046)	(0.0045)	(0.0048)	(0.0046)
Portfolio Return < 0 (%)	39.18	38.41	38.67	34.70	40.08
$R_{LPM} > R_{EMV}$ (%)	59.54	57.23			59.67
SOUTH KOREA/AUSTRALIA					
Mean Portfolio Return	0.0106	0.0109	0.0125	0.0163	0.0115
(std. dev.)	(0.0107)	(0.0103)	(0.0100)	(0.0098)	(0.0103)
Portfolio Return < 0 (%)	37.00	38.28	39.69	37.00	36.75
$R_{LPM} > R_{EMV}$ (%)	50.19	54.80			53.65
TAIWAN/AUSTRALIA					
Mean Portfolio Return	0.0087	0.0072	0.0066	0.0071	0.0071
(std. dev.)	(0.0039)	(0.0033)	(0.0032)	(0.0032)	(0.0034)
Portfolio Return < 0 (%)	40.72	41.74	41.49	36.88	41.36
$R_{LPM} > R_{EMV}$ (%)	58.39	53.27			53.01
THAILAND/AUSTRALIA					
Mean Portfolio Return	0.0135	0.0130	0.0112	0.0147	0.0125
(std. dev.)	(0.0102)	(0.0097)	(0.0094)	(0.0095)	(0.0097)
Portfolio Return < 0 (%)	44.69	39.95	38.80	36.24	41.36
$R_{LPM} > R_{EMV}$ (%)	55.83	56.08			56.85

Notes: Lower partial moment hedges are typically more profitable than Ederington minimum variance hedges, although for all results some variation is seen between currency pairs. Returns to lower partial moment direct hedges generally outperformed those of the Ederington minimum variance hedge in the majority of windows ($R_{LPM} > R_{EMV}$).

Japanese yen can then be compared with those of cross-hedges for each East Asian currency[52]. As noted previously, the Australian dollar is the currency most highly correlated with the East Asian currencies during this period, and has a greater number of significant cointegrating relationships during this period compared with the Japanese yen.

It should be noted at this point that yen and dollar spot returns consistently outperform direct hedge returns for this period, with average returns considerably more profitable than those of either LPM or EMV hedges. However, a noticeable feature is significantly lower standard deviation of returns. Both the Ederington minimum variance ratio hedges and the lower partial moment hedges successfully reduced return variance.

For the purposes of comparing the results with Ederington minimum variance hedges, lower partial moment hedge ratios are estimated with $n = 2$ and $\tau = 0$, which best approximates the minimum variance methodology. Australian dollar direct LPM hedges perform well compared to Ederington minimum variance hedges (Table 8-1), resulting in higher mean portfolio returns and fewer below-zero returns (*Portfolio Return* < *0*). While average returns on the direct hedges underperform the spot, the average return of an LPM hedge is higher than that of an EMV hedge, and returns to LPM hedges outperform those of EMV hedges in the majority of windows ($R_{LPM} > R_{EMV}$). This is particularly relevant to the minimum variance equivalent LPM hedges, which outperform EMV hedges in terms of profitability in 58.26% of windows. Variance of returns was identical for the two hedge types, with a standard deviation of 0.0026 for each.

[52] with the omission of the Indonesian rupiah, as discussed in Section 8.2.

The yen LPM direct hedges (Table 8-2) did not perform quite as well as the EMV hedges, but a similar pattern was observed. Standard deviation of returns for both $\tau = 0$ and EMV hedges were identical (0.0026), although the average LPM hedge return underperformed the average EMV return, and fewer LPM hedges were more profitable than EMV hedges (43.15% of LPM returns were greater than EMV returns). There was less than 1% difference in the number of below-zero returns, although the balance fell in favour of EMV hedges. These results, and those for the Australian dollar, confirm that a lower partial moment ratio with $\tau = 0$ is, as shown theoretically, relatively equivalent to the minimum variance ratio. Further, the standard deviation of returns increases when τ is non-zero.

The best returns were evident for $\tau = -0.5$ hedges, which typify more loss-tolerant investors. Profitability is higher for these hedges (in each case, the average return on the $\tau = -0.5$ hedge is 0.0025, compared with an average return of 0.0005 for EMV hedges). Further, they are significantly more likely to be profitable compared with EMV hedges. The LPM return is greater than the EMV return 65.17% of the time for Australian dollar hedges, and 69.65% of the time for Japanese yen hedges. There are fewer below-zero returns than the Ederington minimum variance hedge, and, while the standard deviation of returns has increased in each case, it remains well below that of the spot position. The outstanding result here is that a slightly more loss-tolerant strategy results in a more profitable direct hedge.

Table 8-2: Performance Results for Portfolios with Japanese Yen Futures, n = 2

	LPM = -0.5	LPM = 0	EMV	Spot	LPM = 0.5
JAPAN					
Mean Portfolio Return	0.0025	0.0003	0.0005	0.0042	0.0006
(std. dev.)	(0.0030)	(0.0026)	(0.0026)	(0.0080)	(0.0027)
Portfolio Return < 0 (%)	42.25	51.98	51.09	35.34	50.83
$R_{LPM} > R_{EMV}$ (%)	69.65	43.15			49.81
MALAYSIA/ JAPAN					
Mean Portfolio Return	0.0163	0.0163	0.0146	0.0154	0.0165
(std. dev.)	(0.0089)	(0.0083)	(0.0081)	(0.0081)	(0.0084)
Portfolio Return < 0 (%)	38.80	37.64	36.62	29.45	37.39
$R_{LPM} > R_{EMV}$ (%)	58.77	54.93			60.18
PHILIPPINES/ JAPAN					
Mean Portfolio Return	0.0128	0.0124	0.0124	0.0141	0.0127
(std. dev.)	(0.0081)	(0.0074)	(0.0074)	(0.0075)	(0.0076)
Portfolio Return < 0 (%)	42.25	35.34	35.72	30.47	40.72
$R_{LPM} > R_{EMV}$ (%)	54.67	55.57			57.75
SINGAPORE/ JAPAN					
Mean Portfolio Return	0.0104	0.0094	0.0084	0.0074	0.0092
(std. dev.)	(0.0051)	(0.0046)	(0.0044)	(0.0048)	(0.0047)
Portfolio Return < 0 (%)	31.50	33.29	34.06	34.70	31.88
$R_{LPM} > R_{EMV}$ (%)	58.39	55.95			58.51
SOUTH KOREA/ JAPAN					
Mean Portfolio Return	0.0177	0.0166	0.0153	0.0163	0.0165
(std. dev.)	(0.0105)	(0.0101)	(0.0099)	(0.0098)	(0.0101)
Portfolio Return < 0 (%)	35.60	36.11	38.03	37.00	38.16
$R_{LPM} > R_{EMV}$ (%)	64.66	52.62			59.28
TAIWAN/ JAPAN					
Mean Portfolio Return	0.0065	0.0065	0.0069	0.0071	0.0072
(std. dev.)	(0.0040)	(0.0033)	(0.0032)	(0.0032)	(0.0034)
Portfolio Return < 0 (%)	43.53	44.05	41.74	36.88	39.44
$R_{LPM} > R_{EMV}$ (%)	49.42	42.77			52.37
THAILAND/ JAPAN					
Mean Portfolio Return	0.0169	0.0158	0.0148	0.0147	0.0157
(std. dev.)	(0.0102)	(0.0097)	(0.0094)	(0.0095)	(0.0098)
Portfolio Return < 0 (%)	36.11	34.44	34.06	36.24	36.49
$R_{LPM} > R_{EMV}$ (%)	57.23	51.86			56.47

Notes: Lower partial moment hedges are typically more profitable than Ederington minimum variance hedges, although for all results some variation is seen between currency pairs. Returns to lower partial moment direct hedges generally outperformed those of the Ederington minimum variance hedge in the majority of windows ($R_{LPM} > R_{EMV}$).

Interestingly, a more loss-averse hedge of $\tau = 0.5$ also results in more profitable hedges on average than EMV hedges, but otherwise has a very similar profit profile to the Ederington minimum variance hedge. The Australian dollar direct hedge has fewer below-zero returns and a greater average return, but has an identical standard deviation of returns and outperforms the EMV hedge in 53.39% of windows. The Japanese yen direct hedge has very similar results, with slightly fewer below-zero returns than the EMV hedge and with more profitable EMV returns in 50.19% of windows.

Cross-hedges do not result in such obvious positive results, but the general profitability trend is consistent. Here, some hedges did outperform the spot, and lower partial moment ratio hedges typically outperform EMV hedges in terms of profit. Again, this is again most noticeable when $\tau = -0.5$ (the exception being the Taiwan/Japan hedge). In general, LPM hedges are more profitable than EMV hedges although this is not always the case. Unlike the direct hedge, there is no significant change in the number of below-zero returns between hedging techniques. Again there is some variation between currencies, although the majority of hedges have relatively equivalent numbers.

The significant decrease in the standard deviation of returns seen in direct hedges was not evident in cross-hedges. The standard deviation of returns for EMV and $\tau = 0$ LPM hedges were generally equivalent to the spot, with little difference between them. However, more significant differences were evident for $\tau = \pm 0.5$ lower partial moment hedges. These consistently resulted in an increase in the standard deviation of returns, as did the direct hedges. However, direct hedge standard deviation was still below that of the spot: with cross-hedges, the standard deviation of $\tau = \pm 0.5$ lower partial moment hedges were consistently higher than the standard deviation of spot returns.

One notable benefit of the lower partial moment hedge ratio, common to both direct and cross-hedges, is that is has the potential to exhibit far less variability than the minimum variance hedge ratio. Hedge ratio stability increases with the level of loss tolerance. A more loss-averse investor, choosing $\tau = 0.5$, is required to rebalance their portfolio more often than a loss-neutral investor, who chooses $\tau = 0$, or a loss-tolerant investor, who chooses $\tau = -0.5$. Hedge ratios for even this small degree of loss tolerance are significantly more stable. Direct hedges require the least rebalancing: the Australian dollar direct hedge (with $\tau = -0.5$) is rebalanced only 7.68% of the time, while the Japanese yen direct hedge is rebalanced only 5.89% of the time. The East Asian currencies with the lowest variance (Table 7-1: Taiwan, Singapore) result in the most stable cross-hedge ratios, with changes 10.37% and 17.93% of the time respectively for Japanese yen cross-hedges, and 9.48% and 18.82% of the time respectively for Australian dollar cross-hedges when $\tau = -0.5$.

As the variance of the hedged currency increases, so too does the frequency of change between periods, however the frequency of rebalancing remains low with a maximum of 31.24% for the Thailand/Australia hedge. This property of the lower partial moment ratio may be beneficial to the hedger, as it implies that less rebalancing is needed to maintain an effective hedge. For each of the two currency sets, Japan and Australia, the stability of estimated hedge ratios ranks in the same order – while the percentage change may vary, the ranking is identical. This implies that it is the characteristics of the hedged currency, rather than the futures being used to form the hedge, that determines the stability of hedge ratios.

Table 8-3 : Hedge Ratios for Portfolios with Australian Dollar Futures, $n = 2$

	LPM = -0.5	LPM = 0	EMV	LPM = 0.5
AUSTRALIA				
Abs. Mean Hedge Ratio	0.7927	0.9347	0.9252	0.9240
(std. dev.)	(0.2696)	(0.1236)	(0.0870)	(0.1443)
Ratio Changed (%)	7.68	69.01	99.74	99.36
MALAYSIA/AUSTRALIA				
Abs. Mean Hedge Ratio	0.5046	0.3032	0.3210	0.3016
(std. dev.)	(0.3062)	(0.3715)	(0.4710)	(0.3365)
Ratio Changed (%)	21.51	64.66	99.87	93.21
PHILIPPINES/AUSTRALIA				
Abs. Mean Hedge Ratio	0.3115	0.1244	0.1408	0.1678
(std. dev.)	(0.1465)	(0.1411)	(0.2022)	(0.1493)
Ratio Changed (%)	24.97	64.53	100.00	95.39
SINGAPORE/AUSTRALIA				
Abs. Mean Hedge Ratio	0.4134	0.2330	0.2377	0.2398
(std. dev.)	(0.2248)	(0.2521)	(0.2705)	(0.2230)
Ratio Changed (%)	18.82	67.48	100.00	96.80
SOUTH KOREA/AUSTRALIA				
Abs. Mean Hedge Ratio	0.4086	0.2364	0.1669	0.2538
(std. dev.)	(0.4019)	(0.3792)	(0.2334)	(0.3372)
Ratio Changed (%)	25.74	67.22	100.00	94.49
TAIWAN/AUSTRALIA				
Abs. Mean Hedge Ratio	0.2954	0.0821	0.0626	0.1204
(std. dev.)	(0.1988)	(0.1054)	(0.0559)	(0.1059)
Ratio Changed (%)	9.48	70.93	99.87	98.72
THAILAND/AUSTRALIA				
Abs. Mean Hedge Ratio	0.5017	0.3142	0.3340	0.3186
(std. dev.)	(0.2731)	(0.3128)	(0.3409)	(0.2887)
Ratio Changed (%)	31.24	67.99	100.00	91.17

There are significant savings in rebalancing costs even when the hedger is loss-neutral. Only a loss-averse investor, who chooses $\tau = 0.5$, is require to rebalance their ratio as often as the Ederington minimum variance ratio, and even then it is slightly less often (for example, 99.36% and 98.72% of windows for Australia and Japan direct hedges, as compared to 99.74% and 99.87% respectively for Ederington minimum variance hedges).

The lower partial moment hedge ratio, therefore, has the potential to cut transaction costs thanks to improved hedge ratio stability, but in a cross-hedge this seems to come at the expense of ratio size. Direct hedges provide the double benefit of reduced hedge ratio sizes, with more loss-tolerant investors ($\tau = -0.5$) potentially using lower hedge ratios than loss-neutral or loss-averse investors and those using the Ederington minimum variance ratio. The Japan and Australia average direct hedge ratios were 0.7718 and 0.7927 respectively, significantly lower than the 0.9116 and 0.9252 found for Ederington minimum variance ratios. However, this effect was primarily evident in the loss-tolerant hedge, and loss-neutral and loss-averse hedgers had no significant difference in hedge ratio magnitude. It should also be noted that the lower partial moment ratios have greater standard deviation than the Ederington minimum variance ratios, so that while ratios may be more stable, they do tend to take more extreme values.

No such behaviour was observed in the cross-hedges, with ratio magnitude bearing little relationship to the level of target return, although ratio standard deviation was likewise higher than that of the Ederington minimum variance ratio.

Table 8-4: Hedge Ratios for Portfolios with Japanese Yen Futures, n = 2

	LPM = -0.5	LPM = 0	EMV	LPM = 0.5
JAPAN				
Abs. Mean Hedge Ratio	0.7718	0.9488	0.9116	0.8894
(std. dev.)	(0.1260)	(0.0611)	(0.0645)	(0.1157)
Ratio Changed (%)	5.89	73.37	99.87	98.72
MALAYSIA/ JAPAN				
Abs. Mean Hedge Ratio	0.3369	0.2022	0.2090	0.2150
(std. dev.)	(0.2155)	(0.2491)	(0.3116)	(0.2228)
Ratio Changed (%)	20.74	65.81	99.87	91.68
PHILIPPINES/ JAPAN				
Abs. Mean Hedge Ratio	0.2961	0.1366	0.1554	0.1657
(std. dev.)	(0.1531)	(0.1630)	(0.1651)	(0.1313)
Ratio Changed (%)	24.33	66.33	100.00	95.39
SINGAPORE/ JAPAN				
Abs. Mean Hedge Ratio	0.3051	0.2338	0.2148	0.2048
(std. dev.)	(0.2126)	(0.1865)	(0.1993)	(0.1886)
Ratio Changed (%)	17.93	68.63	100.00	96.29
SOUTH KOREA/ JAPAN				
Abs. Mean Hedge Ratio	0.3547	0.2211	0.1221	0.2232
(std. dev.)	(0.4389)	(0.3993)	(0.1464)	(0.3415)
Ratio Changed (%)	25.61	68.37	100.00	93.73
TAIWAN/ JAPAN				
Abs. Mean Hedge Ratio	0.2502	0.0844	0.0547	0.0989
(std. dev.)	(0.1578)	(0.0791)	(0.0364)	(0.0723)
Ratio Changed (%)	10.37	68.50	99.87	97.95
THAILAND/JAPAN				
Abs. Mean Hedge Ratio	0.3527	0.2493	0.2328	0.2405
(std. dev.)	(0.2650)	(0.2610)	(0.2341)	(0.2329)
Ratio Changed (%)	28.43	67.48	100.00	91.42

While in most cases the loss-neutral average lower partial moment hedge ratio was similar to the average Ederington minimum variance hedge ratio, those for $\tau = -0.5$ were typically greater than those for $\tau = 0$ or $\tau = 0.5$. Prior studies of lower partial moment hedging have focused on their potential for risk reduction, and have not ventured into an examination of the estimated hedge ratios and their behaviours. This will provide a further avenue for future research.

8.5 Conclusion

The lower partial moment offers benefit to investors as it allows investors to implement hedges according to their risk profile. A more risk-averse investor can implement a more cautious hedging strategy and specify higher target returns, while a less risk-averse investor may hedge with greater risk. While some published research examines the use of the lower partial moment ratio in direct hedges, cross-hedges have remained unexamined, and this chapter begins the process of studying the behaviour of lower partial moment cross-hedges.

Lower partial moment hedges provide profitable alternatives to Ederington minimum variance hedges, both when used in direct hedges, and when used in cross-hedges. Average lower partial moment hedge returns are typically higher than those of Ederington minimum variance hedges, and, in the case of the East Asian cross-hedges, typically outperform the spot. Additionally, direct hedge lower partial moment ratios are usually lower than minimum variance ratios, concurring with the results of Eftekhari (1998) and indicating that there may be transaction cost savings compared with an Ederington minimum variance hedge. In contrast, average lower partial moment ratios for cross-hedges were generally higher than Ederington minimum variance ratios, and there was a higher deviation of ratios from the mean. However, this was offset by greater hedge ratio stability, particularly for higher levels of risk tolerance (τ = *-0.5*). LPM ratios were significantly more stable than EMV ratios, and hence savings in transaction costs based on the frequency of rebalancing would provide savings that may offset the higher average hedge ratios observed in cross-hedges.

This chapter has raised many interesting questions for further research. It leaves the exploration of differing levels of risk-aversion (n) for future study, and instead focuses on the results of differing target returns. Additionally, as the Sharpe measure does not provide an suitable measure of hedge effectiveness for lower partial moment hedges, performance analysis has been based on profitability and the likelihood of below-zero returns. Application of a more sophisticated technique, one that is able to compare the downside risk of spot and Ederington minimum variance hedged positions with that of the lower partial moment hedge, would be preferable, but this is left for future work.

9 Conclusion

The 1990s saw considerable change in the global financial environment. As international trade moved toward seamless transactions, and as the widespread adoption of trans-national electronic banking networks saw faster movement of capital around the world, international capital markets became increasingly integrated (Ayuso and Blanco, 2001). While this integration opened up avenues for investment that had previously been underexploited and facilitated wealth creation in many developing countries, such as those in East Asia, it also created an environment where one stumble by an emerging market could have ramifications felt around the globe. The 1997 crisis may have started in the developing economies of East Asia, but the effects of the crisis spread throughout the international financial system. The most visible symptom of the crisis was the severe decline in the value of Asian currencies experienced by those countries enacting IMF recommendations to liberalise their currency regimes, particularly those of Indonesia and Thailand. The term "currency crisis" has become synonymous with the East Asian crisis, despite the fact that the crisis is better characterised as a credit squeeze (Radelet and Sachs, 1998b). Regardless, significant structural changes took place in the aftermath of the East Asian crisis, and these changes led to a realignment of currency relationships throughout the region.

The 1990s also saw the Japanese economy slow to the point of stagnation. Prior assumptions of regional dominance by the world's second largest economy became less valid, particularly in the latter part of the 1990s when the US economy was revitalised by the dot-com boom and regained some of the ground lost to Japan in the late 1980s (Hayashi and Prescott, 2002). In light of these events, a reassessment of regional currency relationships is warranted.

Further, as international trade and investment with Asia has increased, so too has the importance of prudent and effective investment strategies. Currency hedging is a commonly used technique that can be used to optimise the risk-return trade-off for an investor holding foreign currency. Studies such as Glen and Jorion (1993) have shown that currency hedging brings significant benefits to international investment portfolios, and as investment in East Asia becomes increasingly common, investors will look for appropriate currency hedging strategies.

However, the financial markets of East Asia rarely contain liquid currency derivative products, and suitable offerings on markets outside Asia are rare. Over-the-counter solutions can prove costly and inflexible, and investors may prefer a hedging solution comprised of exchange-traded products. Cross-hedging is an alternative hedging technique that is able to provide the benefits of a currency hedge using liquid, exchange-traded derivatives in closely related currencies. This thesis specifically examines the potential for futures cross-hedging in related regional currencies, namely the Australian dollar and the Japanese yen, both of which are shown to have significant linkages with the currencies of East Asia and each of which provide effective hedges for particular East Asian currencies. It then examines the effectiveness of various hedge ratio derivation techniques when they are implemented as cross-hedges, including the standard Ederington (1979) minimum variance hedge ratio, the error-correction model hedge ratio, and a lower partial moment hedge ratio. The results of this work will be of interest to investors with exposure to international currency markets, as well as academics studying the field of hedging.

9.1 Thesis Summary

This thesis began with a question: At the end of the century, was Japan still the most influential regional currency in East Asia? And does the Australian dollar have any role in the new regional dynamics? Two chapters address this question. In Chapter 5, "Yen Bloc or Koala Bloc? Asian Currency Relationships and the Effects of the East Asian Crisis", techniques used by previous researchers are re-examined to confirm the existence of a yen bloc in Asia. Additionally, it appears that the Australian dollar now plays a similar role to the yen in the East Asian region. Indeed, the linkages between the Australian dollar and the Asian currencies in the post-crisis period show as much support for a "koala bloc" as a yen bloc. Further, simple regression analysis indicates that the US dollar, long the dominant currency in the East Asian region, appears to have declined in importance in post-1997 crisis East Asia, while Australia and Japan are becoming increasingly important regional influences.

Chapter 6, "Cointegration in the Presence of Structural Breaks", seeks to address the more technical aspects of the currency relationships. Importantly, as it can be anticipated that this period includes structural breaks at the time of the 1997 crisis, the Zivot and Andrews (1992) test for a unit root and the Gregory and Hansen (1996) test for cointegration are used to determine the long-run characteristics of the currency series. The results of these tests identify structural breaks in the series during the crisis period, as would be anticipated considering the central bank policy changes that took place during this time. Importantly, these breaks are found using mathematical methods, rather than relying on visual identification as is the case with less sophisticated techniques. The findings confirm that there are significant relationships between the Australian dollar and some East Asian currencies, particularly those of Thailand and

Indonesia. This thesis also finds evidence of relationships between the East Asian currencies and the Japanese yen which confirm the findings of prior studies. These studies used similar results as evidence of a yen bloc, a significant and strengthening relationship between the Japanese yen and East Asian currencies possibly due to regional trade and investment by Japan.

Having established a relationship between the East Asian currencies and their OECD counterparts, this thesis moves on to examine a perennial question in hedging studies: which hedge ratio calculation method provides the most effective outcome during periods of uncertainty? There are myriad ways to calculate hedge ratios, from the simple Ederington (1979) minimum variance hedge ratio to complex GARCH, ARCH and error-correction models that seek to capitalise on the statistical properties of the underlying time series to estimate a more efficient hedge ratio. This thesis restricts itself to two variance-based hedge ratios, the Ederington minimum variance ratio and error-correction model ratio. Additionally, it examines the use of a lower partial moment hedge ratio in a cross-hedge, something that has not been studied in previous published literature.

In Chapter 7, "Cross-hedging Effectiveness in Emerging Markets Experiencing Structural Change", the performance of Ederington minimum variance and error-correction model hedge ratios are contrasted with that of a full, or 1:1 ratio, hedge. The results indicate that the error-correction model hedge, while showing superior in-sample performance, does not necessarily translate into superior out-of-sample performance compared to the minimum variance hedge when hedges are implemented over subsequent 30-day periods. Indeed, the full (1:1) hedge generally outperforms either ratio, particularly during the period incorporating the East Asian crisis and hence the greatest degree of currency instability.

An alternative method of generating hedge ratios is the lower partial moment method first proposed by Fishburn (1977). This technique seeks to minimise investment downside (or losses) while maximising investment upside (or profits). The concept is intuitively attractive – an investor with a foreign currency exposure would wish to take advantage of profits while minimising the potential for losses. The lower partial moment hedge ratio allows the investor to adjust the ratio according to their personal risk and return profile. The use of the lower partial moment is novel, as it has not been previously applied to cross-hedging in published work despite a burst of research activity into its use during the latter part of the 1990s. Chapter 8, "Lower Partial Moment Cross-Hedges", investigates the performance of this ratio derivation technique, implemented here using an iterative estimation technique. The results show that lower partial moment hedges can be effective in minimising downside risk and maximising returns, particularly for direct hedges, and that the lower partial moment ratio generally creates a more profitable hedge than the Ederington minimum variance ratio. Lower partial moment cross-hedges often provide superior returns to those of the Ederington minimum variance ratio hedge, however, unlike direct lower partial moment hedge ratios, cross-hedge ratios are often higher than those derived using the Ederington minimum variance method. This implies that higher transaction costs may be likely when cross-hedging, which must be considered in a practical implementation and factored into the decision to hedge. However, offsetting this is a noticeable increase in the stability of hedge ratios, particularly marked when an investor is more loss-tolerant.

This stability means that less rebalancing may be required, and hence fewer transaction costs may be incurred.

Overall, the results of this thesis provide evidence that an appropriate and well-executed hedging strategy can improve the risk-adjusted performance of a position in an emerging market currency. Focussing on the developing economies of Asia, this thesis shows that cross-hedging using developed economy exchange-traded futures products can be effective in mitigating risk during periods of currency instability and structural change. Hedged positions generally perform better than unhedged (spot) positions, particularly during the period of structural change associated with the 1997 East Asian crisis. Additionally, the investigation into the use of lower partial moment ratios in cross-hedges indicates that these hedges may provide significantly more benefit to a profit-motivated hedger than other forms of ratio estimation.

9.2 Key Contributions of the Thesis

This thesis has two main strands of research:

- an investigation of currency relationships in the East Asian region, and the changes that have taken place since the regime changes of the East Asian crisis period, and
- the use of these relationships to create cross-hedges for East Asian currency exposures, and the ratio estimation techniques that may be used to form these cross-hedges.

As such, it contributes to academic literature in two distinct areas.

In the area of currency relationships, this thesis contributes a number of findings:

- At the most elementary level, it demonstrates the existence of relationships between the Australian dollar and a number of East Asian currencies, and particularly the existence of cointegration relationships with the currencies of Indonesia, Malaysia and the Philippines. This relationship has not been documented in previous studies.
- Granger causality test indicates that the post-crisis relationships between the Australian and East Asian currencies is bi-directional. The relationship reflects the integration of these markets, and indicates a level of co-dependency not observed by previous studies.
- The Japanese yen bloc previously thought to be forming in East Asia has been joined by an equally significant "koala bloc" in post-crisis East Asia. Further, the "yen block" seems to have lost some momentum in the latter part of the 1990s. Existing studies of the yen bloc focus almost exclusively on the pre-crisis period.
- As the study period incorporates the significant regime changes that took place during the 1997 crisis, this thesis uses the Gregory and Hansen (1996) and Zivot and Andrews (1992) tests to characterise time-series data in the presence of structural breaks. These tests have only rarely been applied to currencies, and had not been applied to the currencies in this thesis or during a period of significant currency realignment such as that seen during the crisis. They are shown to better characterise the data over the study period incorporating the structural break, and are used to show the existence of relationships that might have otherwise been incorrectly observed.

Further, in the area of currency hedging, this thesis contributes the following:

- The use of the Australian dollar futures contract as a cross-hedging instrument is shown to be beneficial when cross-hedging East Asian currency positions. The

Australian dollar had not been considered in previous studies of the East Asian region.

- A more comprehensive, non-period-specific study enables the Ederington (1979) minimum variance hedge ratio to be compared with alternative techniques. Most previous studies have used arbitrary period selection, leading to results that cannot be interpreted for general application, and this is particularly apparent in those studies examining the use of error-correction model hedge ratios in cross-hedges. The use of moving windows during the study period enables more general conclusions to be formed. Indeed, when the moving-window technique is used, and when a variety of both in-sample and out-of-sample techniques are used to assess the performance of the hedge, less support is found for the use of error-correction model cross-hedges than has been found in previous studies.
- The lower partial moment hedge is applied empirically to the Australian dollar and Japanese yen direct hedges, which has not yet been documented in the literature. The performance of a lower partial moment hedge is compared with that of the Ederington minimum variance ratio hedge, with the lower partial moment hedge often providing superior returns, fewer negative returns and typically smaller hedge ratios than those estimated using the Ederington OLS regression.
- The lower partial moment hedge ratio is used for the first (published) time in the study of cross-hedging. Lower partial moment cross-hedges are found to be only slightly more profitable than Ederington minimum variance cross-hedges, and they result in higher hedge ratios and greater return and ratio standard deviation. However, again the stability of hedge ratios is far superior to the Ederington minimum variance method, with stability increasing as the target return τ decreases.

9.3 Directions for Future Research

One of the most interesting questions to arise from this work is the bi-directional relationship between the Australian dollar and East Asian currencies, as evidenced by the results of Granger causality testing. While this thesis focussed on the influence of developed market ("western") currencies on East Asian ones, the existence of relationships in the other direction is particularly intriguing. Further, the existence of currency relationships does nothing to explain why they exist in the first place. A greater study of the possible causes of these relationships is warranted, but requires a more detailed economic investigation than was possible in this, a finance thesis.

The developed market currencies in this thesis were restricted in number, and did not include one currency that is likely to have significant links to East Asia – the Euro. The reason for the omission is simple – the Euro had not yet entered circulation during the period of this thesis. The Euro officially commenced circulation in 2002, and once a reasonable period of data has accumulated it will be interesting to see if the Euro has more impact on East Asian currencies than the European proxy used in this thesis, the German mark. Were this thesis to be submitted in 2005, this data would have certainly be included.

The Australian dollar is a focal point of the study, as a currency that is often overlooked in work by non-Australian authors despite being a highly traded currency with sophisticated derivative markets. This thesis attempts to correct this oversight. However this thesis was restricted to the influence of the Australian dollar in East Asia, and the implications for hedging in the East Asian region. Are there other countries or regions whose markets are affected by the Australian dollar? The currencies of the small Pacific island states immediately come to mind as close regional economies whose currencies may be related to the Australian dollar, and indeed the author has already completed a draft of a paper analysing the relationship between these currencies and the policy implications of these relationships. No detailed statistical studies have been made of the currencies of the Pacific, and there are no published studies of cross-hedging in this region. This is an area of research that the author intends to pursue in the future.

Finally, lower partial moment studies are in their infancy, and there are few published papers focussing on this area, particularly in the application of the lower partial moment to currency positions. Further, to the author's knowledge this is the first study in the use of the lower partial moment ratio in a cross-hedge. There is plenty of scope for further research into the lower partial moment hedge and the application of such hedges to emerging market currency positions. In particular, performance characteristics could be examined in more detail, with a focus on appropriate methods with which to analyse the lower partial moment hedge. Additionally, the effect of different levels of risk-tolerance (n) on lower partial moment cross-hedges was not examined in this thesis: this would prove an interesting avenue for future work.

9.4 Concluding Remarks

This thesis has examined emerging market currency hedging from an East Asian perspective, with particular attention paid to the use of Australian dollar and Japanese yen currency futures. It sheds light on inter-regional currency relationships, reflected in increasing currency market cointegration, and uses these relationships to propose techniques that may be used to cross-hedge a currency position during periods of structural change, such as the 1997 East Asian crisis. Several hedge ratio derivation techniques have been examined for their effectiveness when cross-hedging a currency position, including the lower partial moment hedge ratio estimation method, which has previously not been documented in published literature. The results show that hedging during periods of structural change can provide benefits to an investor with an international currency exposure, and different methods of ratio derivation can be used to create effective hedges.

As the markets of East Asia grow and develop, greater integration between regional economic and financial markets can be anticipated. By understanding and capitalising on these links, investors in the region can grow and prosper together.

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